COMMONWEALTH OF PENNSYLVANIA.

DEPARTMENT OF AGRICULTURE.

BULLETIN No. 55.

The Composition and Use of Fertilizers:

PART I.—Chemistry of Plants, Plant-Foods and Soils.
PART II.—Description of Materials Used as Fertilizers.
PART III.—Purchase and Use of Fertilizers.
PART IV.—Arithmetic of Fertilizers.
PART V.—Average Composition and Value of Fertilizing Materials and of Farm Crops.

BY L. L. VAN SLYKE, Ph. D.

PUBLISHED BY DIRECTION OF THE SECRETARY.

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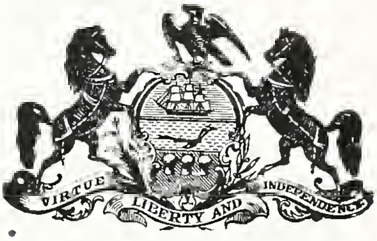
VIRTUE
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COMMONWEALTH OF PENNSYLVANIA.

Department of Agriculture.

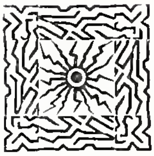
HARRISBURG, PA., *December 30, 1899.*

Under the authority of the Act creating this Department, the Secretary is authorized to publish from time to time such Bulletins of information as he may deem useful and advisable.

The Bulletin herewith presented, prepared by Dr. Van Slyke, of the New York Agricultural Experiment Station, at Geneva, contains information of a most valuable kind to the practical agriculturalist. The question of what fertilizer to use, and how and when to use it, is one that comes to every farmer for determination, and there is less good judgment shown in this direction than perhaps in any other with which the modern agriculturalist has to deal. For this the farmer is not alone to blame, since comparatively little has been done to educate him in the economic and intelligent use of plant-food. This Bulletin is intended to supply this need, and the high scientific standing of its author is a guarantee that its facts can be depended upon as being reliable and up to date.

It is hoped that those who receive a copy will carefully study its contents and preserve it for future reference.

JOHN HAMILTON,
Secretary of Agriculture.



INTRODUCTION.

The matter in this bulletin is to be carefully studied, not merely read, if one expects to obtain the greatest benefit from it. It is suggested that the bulletin be taken up in small portions at a time and be studied constantly, going back to parts previously studied until they are clearly understood. Many may find that Part I especially will need to be studied in this way and it may be well to pass on to the following portions and come back to Part I from time to time. In this way its importance will be more fully realized and also its connection with the other parts. The bulletin should be kept at hand for constant reference.

Until fifty years ago, agriculture was without a scientific working basis. To the investigations of the illustrious German chemist, Justus von Liebig, we largely owe the advances that have been made in agricultural methods during the past half century. The following four laws, which form the foundation of modern agricultural practice. were fully established by Liebig:

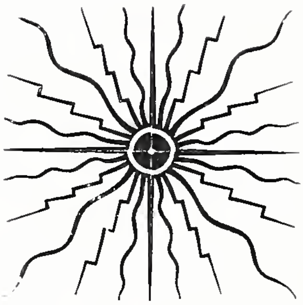
First. "A soil can be termed fertile only when it contains *all the materials requisite for the nutrition of plants*, in the required quantity, and *in the proper form.*"

Second. "With every crop, a portion of these ingredients is removed. A part of this portion is again added from the inexhaustible store of the atmosphere; another part, however, *is lost forever if not replaced by man.*"

Third. "The fertility of the soil remains unchanged, if all the ingredients of a crop are given back to the land. Such a restitution is effected by *manure.*"

Fourth. "The manure produced in the course of husbandry is *not* sufficient to maintain permanently the fertility of a farm; it lacks the constituents which are annually exported in the shape of grain, hay, milk and live stock."

These four laws of Liebig contain a clear statement of the principles underlying the use of fertilizers; but, to understand their meaning with satisfactory clearness, we must know something more in detail about such subjects as the following: the constituents of plants; the materials of plant-food; the constituents of soils; the relations of soils and plants; the sources and composition of different forms of plant-food; what forms and quantities of plant-food to use on different soils and crops, and other similar questions.



THE COMPOSITION AND USE OF FERTILIZERS.

By L. L. Van Slyke, Ph. D., Geneva, New York.

PART I.

THE CHEMISTRY OF PLANTS, PLANT-FOODS AND SOILS.

1. The Constituents of Plants.

Elementary Composition of Plants.—The number of different kinds of plants growing on the earth is estimated at not less than two hundred thousand; and these, with all their variation of stem, foliage, flower and fruit, are made from about a dozen different chemical elements. Indeed, the greater bulk of the vegetable kingdom is made from only three different elements.

By a *chemical element*, we mean *any substance which cannot, by any known means, be separated into two or more different kinds of matter.* Thus, oxygen is an element because it contains only one thing, oxygen, so far as we now know. From pure gold, nothing but gold can be obtained; hence, gold is an element. Similarly, nitrogen, carbon, phosphorus, etc., are elements.

At present about seventy different elements are known, and of these seventy only fourteen are used in the production of plants; while of these fourteen only eleven or twelve are really essential to plant growth. The following list contains the names of the elements that occur in plants: Carbon, oxygen, nitrogen, hydrogen, potassium, phosphorus, calcium, magnesium, sulphur, iron, chlorin (sodium, silicon manganese).

These few elements we may regard as a kind of chemical alphabet of the vegetable world. We do not find these elements simply tumbled together in promiscuous heaps in the formation of plants. Somewhat as the letters of our alphabet unite to form words, so the chemical elements are united to form chemical compounds, and these compounds are mixed together in a variety of ways to form plants.

Classes of Chemical Compounds in Plants.—It will be of interest in passing to notice some of the more common kinds of chemical compounds found in plants.

First. There is a most important and extensive group of compounds, each containing carbon, hydrogen, and oxygen. The class, as a whole, is known by the name of *carbohydrates.* The most common members of this class are sugar, starch, woody-fiber, vegetable gums, etc.

Second. We have another class distinguished for the valuable food-constituents contained in it, known in general as *proteids.* As a representative of this class, we may mention the gluten or sticky portion of wheat flour. This contains, besides the three elements of carbohydrates, three other elements—nitrogen, phosphorus and sulphur.

Third. We have the vegetable oils, from which come our linseed, castor, olive, cottonseed, and other vegetable oils of commercial importance.

Fourth. We may mention as another class the vegetable acids—for example, the tartaric acid of grapes, present as a compound of tartaric acid and potassium, containing the elements, carbon, hydrogen, oxygen and potassium; citric acid, found in lemons, currants, cherries, strawberries and similar fruits; malic acid, in apples, etc.

Fifth. We have that extremely important class of compounds which give characteristic flavors to many plant products, particularly the flowers and fruits.

Sixth. There may be mentioned in passing the very widely distributed substances of vegetable origin, used for medicinal purposes, such as quinine, morphine, strychnine, etc.

The exact number of different compounds in the vegetable kingdom formed from our dozen elements is not known but must be very large, as can be inferred from the character of the few referred to.

Classification into Air-Derived and Soil-Derived Elements.—The elements necessary to the growth of plants may be divided into two quite distinct classes, which have important and marked differences. These two classes are: (a) Air-derived elements. (b) Soil-derived or mineral elements.

(*a*) *Air-Derived Elements.*

Carbon,
Oxygen,
Hydrogen,
Nitrogen.

(*b*) *Soil-Derived Elements.*

Potassium,
Phosphorus,
Calcium,
Magnesium,
Sulphur,
Iron,
Chlorine,
Sodium,
Silicon,
Manganese.

It is usual among writers on agricultural chemistry to call these classes organic and inorganic elements, but this use of these words is extremely inaccurate; for any element may be either organic or inorganic, according as it is or is not a part or product of an organized body. Oxygen, as it exists in the air, is inorganic matter; but when, through vital processes, it becomes part of an animal or plant, it is organic.

These two classes of elements differ in three important particulars, as follows:

First. The elements of the first class are derived exclusively from the air, either directly or indirectly; while those of the second class come exclusively from the soil.

Second. Air-derived elements disappear, for the most part, in the form of gases, when a plant is burned; while the soil-derived elements, usually the smaller part, are left in the form of a residue or ash, upon which further heating will not have any effect. Some carbon and oxygen and nitrogen are always found in the ash, while slight quantities of chlorine, sulphur and phosphorus are apt to be driven off by heating. The two classes of elements are, therefore, not so sharply defined in this regard as they are in respect to the sources from which they come.

Third. These two classes of plant-food elements differ in a striking way in regard to the quantities in which they are used as food by plants. *The air-derived elements constitute more than ninety-five per cent. of the whole vegetable kingdom;* while the mineral or soil-derived elements occur in small quantities, varying from a fraction of one per cent. up to ten per cent.

This fact has a most important application in enabling us to control our yield of crops. Man cannot, to any appreciable extent, at least economically, control directly most of the air-derived elements in feeding plants; but he can do so indirectly through the soil-derived elements. In other words, by looking after less than five per cent. of the materials used by plants as food, he can, to a large extent, control the other ninety-five per cent., other conditions being favorable.

Classification into Acid-forming Elements and Metals.—Of the fourteen elements which are found in plants, some are spoken of as *non-metallic* elements or *acid-forming* elements, because, in certain combinations, these elements form well known acids. The other elements are known as *metallic elements or metals.*

(*a*) *Acid-forming Elements.*

Carbon,
Hydrogen,
Oxygen,
Nitrogen,
Phosphorus,
Sulphur,
Chlorine,
Silicon.

(*b*) *Metals.*

Calcium,
Potassium,
Sodium,
Iron,
Magnesium,
Manganese.

Acids and Salts.—(*a*) *An Acid is a compound containing an acid-forming element combined with hydrogen and oxygen*, or in some cases, with hydrogen alone. The following examples will serve to illustrate:

Nitrogen+oxygen+hydrogen forms *nitric acid* (aqua fortis).

Phosphorus+oxygen+hydrogen forms *phosphoric acid.*

Sulphur+oxygen+hydrogen forms *sulphuric acid* (oil of vitriol).

Chlorine+hydrogen forms *hydrochloric acid* (muriatic acid).

(*b*) *A salt is a compound formed by putting a metal in the place of the hydrogen of an acid;* that is, an acid differs from a salt simply in having a metal where the acid has hydrogen. Every acid has a salt corresponding to it. For example, as stated above, *nitric acid* consists of *nitrogen* and *oxygen* and *hydrogen.* Now, if we put the metal *potassium in the place of hydrogen* we have a compound containing *nitrogen + oxygen + potassium* (in place of hydrogen). This compound is the *potassium salt of nitric acid* and is called nitrate of potash or potassium nitrate.

Phosphoric acid consists of *phosphorus* and *oxygen* and *hydrogen;* in place of *hydrogen* put one of the metals, as *calcium*, and we have a compound containing

Phosphorus and *oxygen* and *calcium* (in place of hydrogen), which is the *calcium salt of phosphoric acid* and is called *calcium phosphate* or phosphate of lime.

Similarly, if a metal, as magnesium, is put in the place of the hydrogen of sulphuric acid, we have the *magnesium salt of sulphuric acid* or *magnesium sulphate*, familiar to us as Epsom salt. If in hydrochloric (muriatic) acid, we put some metal as sodium in place of the hydrogen, we have a compound consisting of sodium and chlorine, which is the *sodium salt of hydrochloric acid* and is called *sodium chloride*, sometimes called muriate of soda, familiar to us as common salt.

The word "salt" as used in chemistry applies to a great number of compounds, and many of the substances we have to deal with in speaking of fertilizers are *chemical salts;* that is, *substances formed by putting some metal in place of the hydrogen of some acid.*

Carbon.—(*a*) *Importance.*—The element carbon may be called the central element of all animal and vegetable substances; for there is not a living thing, from the smallest cell to the giant tree, which does not contain carbon as a necessary constituent and in relatively large proportions. That all vegetable and animal substances contain carbon can easily be shown by simply heating them sufficiently, and thus causing them to *blacken* or *char.* When, for example, wood is heated, the different air-derived elements of which it is composed are driven off in one form or another, but the carbon is the last to go, and remains behind as a black substance or charcoal, unless heated higher, when it too disappears, that is, burns.

(*b*) *Source.*—Carbon usually occurs in nature united in compounds with other elements. Thus, most products of plant life contain carbon combined with the elements hydrogen and oxygen; such are starch, sugar, and cellulose or woody fibre. Carbon combined with oxygen occurs in the air in the form of carbon dioxide, commonly called carbonic acid gas. Carbon, when combined with oxygen and some element such as calcium, occurs in the form of carbonates; for example, marble, limestone, and chalk are chemically known as calcium carbonate or carbonate of lime.

Carbon by itself or in the free condition, that is, not united with any other elements, is familiar to us in several different forms; the most common of these are (1) diamonds; (2) graphite, which is used in the manufacture of lead-pencils; (3) ordinary wood-charcoal; (4) lamp black; (5) animal charcoal; (6) mineral coal. Excepting diamond these forms of carbon are more or less impure, containing some other things mixed with the carbon.

Hydrogen.—(*a*) *Source.*—The element hydrogen is nearly always found combined with other elements. It combines with oxygen to form water. Hydrogen also occurs in most animal and vegetable substances, such as various kinds of wood, fruits, etc., in which it is combined with the elements, carbon and oxygen. Hydogren is always present in all kinds of acids.

(*b*) *Description.*—Hydrogen, in the uncombined form, is a gas that resembles air in that it has neither color, smell, nor taste.

Oxygen.—(*a*) *Source.*—Oxygen is the most abundant of all the elements. The compounds which contain no oxygen are few in number. Oxygen forms nearly one-half of the crust of the earth; eight-ninths of water; about one-fifth of air; and one-half of all animal and vegetable matter.

Oxygen occurs in the air uncombined with other elements.

Oxygen, combined with the elements carbon and hydrogen, or with carbon, hydrogen and nitrogen, is found in substances which go to make up animals and vegetables.

(*b*) *Description.*—As might be inferred from knowing that oxygen in the uncombined state forms part of the air, oxygen is a gas having no color, taste or smell.

Oxygen is a very active substance from a chemical point of view. It tends to unite with nearly all of the elements. In all forms of burning, the oxygen of the air is simply uniting with other elements. Thus, in a coal fire the oxygen unites with the carbon of the coal. The heat is produced by the union of the two elements.

Nitrogen.—(*a*) *Source.*—Nitrogen occurs in nature in the following forms:

(1) As a constituent of *air*.
(2) In the form of *ammonia*.
(3) In the form of nitric acid and *nitrates*.
(4) In various other forms in plants and animals.

(1) Nitrogen in Air.—Nitrogen, uncombined with other elements, forms about four-fifths of the air. Since the nitrogen in the air is not combined, we can perceive its properties for ourselves, and our observation shows us that it is a gas, which has neither color, taste nor smell.

(2) Nitrogen in Ammonia.—Nitrogen combined with the element hydrogen forms ammonia. Ammonia is present in the air in very small quantities. Ammonia is formed when vegetable and animal substances containing nitrogen decompose.

Ammonia is a colorless gas, and it is this gas dissolved in water which is familiar to us as ammonia water or "Spirits of Hartshorn," and which causes the peculiar odor of "hartshorn."

Ammonia unites with different acids and forms salts somewhat as metals do; these salts we call *ammonium salts*, compounds which do not generally have any odor like ammonia. Thus, ammonia combined with sulphuric acid forms *ammonium sulphate*, commonly called sulphate of ammonia; ammonia, combined with hydrochloric acid, forms *ammonium chloride*, sometimes called muriate of ammonia, also known as *sal ammoniac*.

(3) Nitrogen in Nitrates.—Nitrogen, combined with hydrogen and oxygen, forms *nitric acid or aqua fortis*. If in nitric acid a metal as sodium, for example, takes the place of hydrogen, we have formed a sodium salt of nitric acid or a *nitrate*, called sodium nitrate, or nitrate of soda.

When animal and vegetable substances decompose in rather warm, moist places, the nitrogen is changed into nitrates. This change of the nitrogen of organic matter into nitrates is caused by germs called *bacteria*, which are very small living vegetable organisms, and which exists everywhere in enormous numbers. The process is known as "*nitrification*," the details of which will be noticed later.

(4) Nitrogen in Animals and Plants or OrganicNitrogen.—Nitrogen, combined with the elements, hydrogen, carbon and oxygen occurs in plants and in animals. Such substances for example are the casein or curd of milk, the gluten or gummy portion of wheat, the fibrin of blood, the white of egg, etc. When such compounds decompose, the nitrogen is first changed into ammonia, and then, under proper conditions of warmth, moisture and access of air, into nitric acid and nitrates. The nitrogen existing in animals and plants is generally called *organic nitrogen.*

(*b*) *In what Forms Nitrogen is Useful to Plants.*—Plants can use nitrogen in three different forms, viz:

(1) As nitrogen gas or uncombined nitrogen.
(2) In the form of ammonia.
(3) In the form of nitrates.

All plants can not use nitrogen in any of these three forms equally well, but each form is found specially suited to certain kinds of plants as will be noticed.

(1) Nitrogen Gas used by Plants.—Although we have nitrogen gas or uncombined nitrogen existing in the air in enormous quantities, still the number and kinds of plants which can use the nitrogen of the air is not large. In general, those plants which are called *leguminous*, such as the bean, pea, clover, alfalfa, etc., can take uncombined nitrogen from the air.

(2) Nitrogen of Ammonia used by Plants.—The leaves of some plants have the power of absorbing ammonia directly from the air and obtain nitrogen in this way, but only in very small quantities. Some plants obtain nitrogen from ammonium salts through the soil, but for the most part, the compounds of ammonia are changed into nitrates in the soil before being used by plants.

(3) Nitrogen of Nitrates used by Plants.—The largest part of the nitrogen obtained by most plants is taken up by their roots from the soil *in the form of nitrates*; that is, nitric acid combined with some metal, as calcium, sodium or potassium. As already stated, most of the nitrates used by plants are formed by changing into nitrates the ammonia compounds and organic substances in the soil by the process called *nitrification.* Hence, *nitrogen, in the form of nitrates,* is the most *available* form for most plants; that is, it can be most readily taken up and used by plants as food.

Phosphorus,—(*a*) *Description.*—Phosphorus, when uncombined with other elements, is a yellowish, waxy-looking, solid substance. It is soft and can be cut as easily as ordinary beeswax. It is very poisonous. It takes fire very easily and, therefore, has to be kept under water. When phosphorus burns, it simply unites with the oxygen of the air, forming a compound which contains oxygen and phosphorus; this compound of oxygen and phosphorus is commonly called phosphoric acid.

(*b*) *Source.*—Phosphorus is always found in nature combined with other elements. It occurs combined with oxygen and calcium (or lime) and this compound is called *calcium phosphate or phosphate of lime.* It also occurs in soils as phosphate of magnesia, and phosphate of alumina and iron. Calcium phosphate or phosphate of lime is found in some minerals and in the bones of animals.

(*c*) *Importance of Phosphorus Compounds.*—The phosphates, like the nitrates, are found everywhere in the soil and are of great value in their relations to plants. The phosphates found in the bones are taken into the animal body in the food. All plants used as food contain small quantities of phosphorus compounds which they get from the soil. The phosphates taken into the body are partly given off in the excrement and urine.

Sulphur.—(*a*) *Source.*—Sulphur, uncombined with other elements, is found near volcanoes. Combined with other elements, sulphur is found in a great many minerals. Sulphur is also found in vegetable and animal products, combined with the elements carbon, hydrogen and nitrogen. The properties of the element sulphur are too well known to need any description.

(*b*) *Compounds.*—When *sulphur* is combined with *hydrogen* and *oxygen* in certain proportions it makes *sulphuric acid*, commonly called *oil of vitrol.* When the hydrogen of sulphuric acid has its place taken by any metal, a *sulphate* is formed. For example, when the metal potassium takes the place of the hydrogen of the sulphuric acid, a salt is formed known as *potassium sulphate* commonly called *sulphate of potash;* from sulphuric acid in the metal calcium is formed the salt *calcium sulphate*, commonly known as *sulphate of lime* or *gypsum.*

Chlorine.—(*a*) *Description.*—Chlorine, when not combined with other elements, is a greenish-yellow gas, having a very suffocating odor. The gas is very poisonous and has very active chemical power.

(*b*) *Source.*—Uncombined chlorine is never found in nature. We commonly know chlorine only in its compounds. Chlorine combined with hydrogen forms hydrochloric or muriatic acid. Chlorine combined with any metal forms *chlorides*, commonly known also as *muriates.* For example, *chlorine* combined with the metal *sodium* forms a compound which is called *sodium chloride* or chloride of sodium, or muriate of soda; and this sodium chloride is the common salt familiar to us in every-day experience. *Chlorine* combined with the metal *potassium* forms *potassium chloride* commonly called *muriate* of *potash.*

Silicon.—*Source.*—Silicon, next to oxygen, is the most abundant element in the earth. It does not occur uncombined with other elements. Silicon combined with oxygen forms a compound commonly called *silica.* Quartz and sand are nearly pure silica.

Silicon combined with oxygen and several of the metallic elements, such as sodium, potassium, calcium, etc., forms compounds which are called *silicates.* The feldspars are silicates; clay is a silicate. Ordinary glass consists of a mixture of silicates.

Calcium.—*Source.*—The metal calcium is always found in nature combined with other elements. The compounds of calcium are ordinarily known as *lime* compounds, because calcium, when combined with oxygen to form a compound known as calcium oxide, was called lime, and this calcium oxide or lime was supposed to be present in calcium compounds.

Calcium combined with oxygen and carbon forms a compound which is known as *calcium carbonate or carbonate of lime.* Limestone, marble, chalk, eggshells and coral consist of calcium carbonate or carbonate of lime. Calcium and sulphuric acid form a compound known as *calcium sulphate or sulphate of lime;* gypsum and plaster of Paris are familiar forms of calcium sulphate; it is often called simply "*plaster.*" Gypsum is calcium sulphate containing about twenty-one per cent. of water.

Calcium combined with oxygen, as already noted, forms calcium oxide, which is commonly known as *lime or quicklime.* This is made by burning some form of calcium carbonate, as, limestone, oyster shells, coral rock, etc.; the carbon dioxide (carbonic acid) is driven off by the heat, and calcium oxide or quicklime remains.

When quicklime is exposed to the air, it slowly absorbs moisture and carbon dioxide and is changed back into calcium carbonate. When quicklime is changed into calcium carbonate (carbonate of lime), the lime is said to be *air-slaked.*

Potassium.–*Source.*—The metal potassium is never found uncombined in nature. It is a constituent of many minerals. The decomposition of these minerals gives rise to the presence of potassium compounds everywhere in the soil. It is taken up by plants; and when vegetable material is burned, the potassium remains behind, chiefly as potassium carbonate. When wood-ash is treated with water, or "leached," the potassium carbonate is dissolved out, forming "lye," and this, evaporated to dryness, leaves impure potassium carbonate, which is commercially known as *potash.*

In using the term *potash* in connection with fertilizers, potassium oxide is always meant. The compounds of potassium are commonly called *potash compounds,* because it was formerly supposed that potassium oxide or potash was present in all of them.

Potassium combined with chlorine forms potassium chloride or chloride of potash or *muriate of potash*, etc. Potassium and sulphuric acid form potassium sulphate or *sulphate of potash*. Potassium and nitric acid form potassium nitrate, also called *nitrate of potash* and *saltpeter*.

Sodium.—*Source.*—Sodium occurs in nature mostly in combination with the element chlorine in the form of *sodium chloride* or *common salt*. It is found everywhere in the soil, but usually in small quantities. Sodium and nitric acid form *sodium nitrate or nitrate of soda*, commonly known as Chili saltpeter.

Magnesium, Iron and Manganese.—These elements, especially magnesium and iron, are present as essential constituents of plants. They exist in various forms of combination with other elements.

2. Classification and Definition of Terms used in Connection with Fertilizers.

A Fertilizer *may be defined as any substance which, by its addition to the soil, will produce a better growth of plants* under favorable conditions.

The materials which come under the head of fertilizers are numerous in kind, and different both in form and the manner in which they act.

The following tabulated classification, while not strictly accurate in every respect, will serve to give a good general idea of the number and relations of the terms used in speaking of fertilizers:

FERTILIZERS, ...
- I. Direct or Nutritive.
  - 1. Natural, ...
    - Stable manure.
    - Refuse vegetable matter.
    - Green crops for plowing under.
    - Cotton-seed, etc.
    - Muck, marls, etc.
    - Animal refuse.
  - 2. Artificial, ...
    - Commercial, Chemical, or Prepared.
      - a. Complete or general.
      - b. Incomplete or special.
- II. Indirect or Stimulant.
  - Lime.
  - Gypsum.
  - Salt, etc.

These terms are, in general, loosely and indiscriminately used, as their meaning is often misunderstood; and so an attempt will be made here to define them in accordance with the best usage of the terms.

A Direct Fertilizer *is one containing elements of plant-food that are available at once* or easily become so; that is, which can be taken up and used either immediately or within a short time by plants.

The term **Available** is applied to plant-food which is *soluble*, that is, in such a condition that the roots of the plant can take it up readily in solution.

Plant-food is **Unavailable**, when it is in such a form, that the roots of the plant fail to take up any part of it. A large proportion of plant-food present in the soil is unavailable because insoluble, but by the action of air, water, carbonic acid, etc., it is gradually changed to soluble or available forms, which the plant can take up and use. As will be noticed later, phosphoric acid in the form of *insoluble* calcium phosphate or phosphate of lime is unavailable as plant-food, but when converted into a superphosphate or *soluble* calcium phosphate, it becomes available. Organic nitrogen is unavailable until it is changed into nitrate nitrogen. Unavailable plant-food is *potential* food or food in reserve.

An Indirect Fertilizer *is one which does not furnish to the soil any needed plant-food and which may not be plant-food at all, but which is characterized by the way in which it acts on the matter already in the soil, changing more or less of it from unavailable plant-food to an available form, or producing some other beneficial effect in the soil.* For example, lime, gypsum, salt, etc., are indirect fertilizers, as they are generally used by farmers. Later some attention will be given to the action of some of the most familiar indirect fertilizers. They are commonly used by farmers, not because the elements they furnish are lacking in the soil, but because they can act upon unavailable plant-food and render it available, or because they may have some beneficial influence upon the mechanical condition of the soil.

Natural Fertilizers include the solid and liquid excrement of animals, all kinds of vegetable refuse, green crops for plowing under, cotton-seed, mucks, marls, refuse animal matter, etc.

Artificial Fertilizers are also known by such names as *commercial fertilizers*, *chemical fertilizers*, *etc.*, and are artificial preparations or mixtures of fertilizing materials sold under trade names. The fertilizing materials used in making these mixtures include the substances found in natural deposits and by-products of numerous industries, which are obtainable by farmers only through the channels of trade. Some substances which might be classed as natural fertilizers, such as cotton-seed meal and tobacco stems, are also included among the materials of artificial fertilizers.

Complete Fertilizers, known also as *general fertilizers*, are those which contain nitrogen, phosphoric acid and potash.

Incomplete Fertilizers, also called *special fertilizers*, are those which contain only one or two of the three constituents, nitrogen, phosphoric acid and potash.

There is a common practice among farmers and dealers of calling all commercial fertilizers "phosphates," regardless of whether they contain any phosphates at all or not. The practice is clearly objectionable, because a phosphate is not the only fertilizing constituent presented in commercial fertilizers,—in some cases it may be entirely absent. The term "superphosphates" applies truthfully to many commercial fertilizers, but even these can not be correctly spoken of as simply "phosphates." This common usage of the term "phosphate" for any form of fertilizer emphasizes the fact that there has been a tendency to overestimate the value and importance of this constituent, resulting in large applications of it without regard to the needs of soil or crop.

3. The Relations of the Different Elements of Plants to Fertilizers.

Carbon.—We know that carbon must be an important element in plant-food, since it forms nearly one-half of the solid portions of plants. Notwithstanding the fact that carbon forms so large a portion of plants, it has no importance as an *active* food constituent of *direct* fertilizers. This statement may appear strange and the question may be asked, "why is not carbon to be regarded as an essential constituent of direct fertilizers?" The answer is that the carbon of plants comes from the carbon dioxide (carbonic acid gas) of the air, and the air furnishes an inexhaustible and available supply of this substance. We do not, therfore, need to add carbon to the soil in order to supply the needs of plants. However, some recent investigations seem to indicate that some carbon is probably taken into the plant through the roots and that forms of carbon other than carbon dioxide may be found to be useful in supplying plants with their carbon food.

Carbon dioxide is present in the atmosphere to the extent of three parts in 10,000 parts of air. Though present in so small proportions, we have in the atmosphere resting upon one acre of ground more than twenty tons of this gas, an amount sufficient to supply sixteen times as much carbon as any crop would ever be likely to need. The supply of carbon dioxide in the air is kept up by the burning of fuel, from the breath of all animals, and from the natural processes of decay of organic matter. A ton of good coal, in burning, produces over three tons of carbon dioxide. The people in a town of ten thousand inhabitants breathe out every twenty-four hours not less than five tons of carbon dioxide. This amount would furnish enough carbon to grow several acres of corn with an extremely large yield.

Carbon dioxide performs a service for plants in another way when it is carried into the soil in rain water, by means of the dissolving action it has upon some of the mineral plant-food constituents of the soil. In this way it acts as indirect fertilizer.

Oxygen.—The oxygen which plants use comes largely from the air, of which it constitutes about one-fifth, and this amounts to about ten thousand tons an acre. Some of the oxygen that plants use for tissue formation and elaboration of plant compounds is supplied in the form of water, which is a compound of oxygen and hydrogen.

Water (Hydrogen and Oxygen).—Growing plants consume a larger amount of water than of any other compound. More or less water is separated within the plant into its constituent elements, hydrogen and oxygen, and these are then built into the tissues and compounds which it is the office of the plant to elaborate. In this manner, water acts as a *direct fertilizer*. The water is supplied to the soil by rains, and from the soil it is taken into the plant through the delicate root-hairs. Most of the water that enters a plant through the roots is evaporated finally from the leaves into the air as water vapor, this process being known as *transpiration*. The amount of water transpired into the air is immensely greater than that retained in a plant. Some plants exhale their own weight of water during twenty-four hours in hot dry weather. A crop of barley grown on an acre of land may weigh 5,000 pounds, grain and straw included. Of this there will be 500 pounds of water and 4,500 pounds of dry or solid matter, to produce which the crop has evaporated from the growing plants during their period of growth not less than 700 tons of water, an amount of water which would require a railway train of thirty-five cars to carry. *Under average conditions, 300 pounds of water will have to pass through a plant into the air, while one pound of solid matter is being added to the plant.* The need for enormous quantities of water in growing crops is obvious, but, in regions adapted to agriculture, plants usually receive from rain all the water (oxygen and hydrogen) needed. Hence, these plant-food elements do not usually enter into a farmer's consideration, when he is planning to supply his crop with needed plant-food. However, it is essential that the losses of water from the soil shall be controlled, as can be done by proper means of tillage, keeping up supply of humus, etc. When water is supplied to plants by irrigation, it is very properly regarded as a fertilizer, and an extremely important one.

Nitrogen.—Experiments have shown that nitrogen is essential to the growth of plants; that the quantities of nitrogen available as plant-food are very small; that nitrogen is one of the first elements in the soil to be used up; that, of all fertilizing elements, nitrogen is and always has been the most expensive.

Phosphorus.—The fact that phosphorus compounds are absolutely necessary for the maturity of plants indicates that phosphates are essential to complete fertilizers. Soils become deficient in available phosphates quite rapidly, especially in grain-growing regions.

Sulphur.—Sulphur is known to be an essential constituent of plant-food. So far as known, plants take it up and use it in the form of sulphates. As a rule, there appear to be in all soils amounts of sulphates sufficient to supply indefinitely all the demands of crops. As the quantity of sulphur used by plants is very small, soils do not readily become exhausted of this element. Therefore, we do not need, in general, to add sulphur compounds to the soil. Calcium sulphate (sulphate of lime) and potassium sulphate (sulphate of potash) are often present in commercial fertilizers, but they are generally used not on account of the sulphur they contain. Some forms of sulphur compounds, sulphate of iron, for example, render a soil barren, when present in any considerable quantity.

Chlorine.—While chlorine is known to be an essential constituent of plant-food, the circumstances which require its addition to the soil appear extremely rare, except in some cases where it may be used for an indirect benefit. It is added to fertilizers in considerable quantities in the form of potassium chloride (muriate of potash) but this is largely because this happens to be the cheapest form in which potash can usually be obtained. It is the effect of the potash, not of the chlorine, that is desired. An excess of compounds of chlorine in soils renders them barren.

Silicon, in the form of silica and silicates, is abundant in all soils, and does need special attention in connection with fertilizers. By many it is regarded as useless to plants.

Calcium.—All plants require calcium or, as it is more commonly called, lime. While many soils appear to contain an inexhaustible supply of lime, there is quite often need of special attention to this element of plant-food, in fact, rather more than was formerly believed necessary.

Potassium.—Experiments show that when potassium (or potash) compounds are lacking in the soil, the plant suffers greatly, though it does not necessarily die. The development of the woody parts of plants and the fleshy portions of fruits seems to be largely dependent on the influence of potassium compounds. As potash is taken up by vegetation, most soils under constant cultivation sooner or later become deficient in potash, and this loss must be supplied by means of fertilizers. Therefore, potassium (potash) compounds are regarded as essential constituents of direct fertilizers.

Sodium in the form of sodium chloride (common salt) is found in small quantities in all soils. While it appears as a regular, though small, constituent of plants, it is a disputed question whether it is a necessary constituent of plant-food, but the weight of evidence appears to show that it is not necessary and that the requirements of plants do not call for the addition of sodium compounds to fertilizers. In the case of nitrate of soda, it is not the sodium, but the nitrogen in the form of nitrate, which gives the compound its value as plant-food. It merely happens that the nitrate can be furnished most cheaply in this form. The application of sodium chloride as an indirect fertilizer has been found, under some conditions, to be attended with beneficial results.

Magnesium is a necessary constituent of plants, but, so far as known, it rarely needs to be added to a soil. There are some magnesium compounds existing as impurities in the German potash salts, and when these latter are used, some magnesium is added to the soil incidentally.

Iron, though used by plants in very small quantities, is an essential constituent of plant-food. It is rarely, if ever, absent from cultivable soils, and hence does not need to be considered in connection with commercial fertilizers.

4. The Specific Action of Different Elements of Plant-Food upon Plants.

The question is often asked in connection with the different constituents of plant-food regarding the function each performs in plant growth. It is well known that each element contributes to the building of definite compounds contained in the plant, and that each has one or more special offices to fulfill. While the specific action and functions of the different elements are not clearly understood in all details, much is known, and we now present a brief outline of the facts relating to this subject, so far as known.

Carbon is a constituent of nearly all the compounds, except water, found in plants, such as starch, fibre, sugar, fat or oil, proteids, acids, etc. Hence, its function is to supply its necessary part of the material found in such compounds. Plants take in their supply of carbon dioxide chiefly through their leaves directly from the surrounding air. In the cells of the leaves, the carbon dioxide, in the presence of sunshine, is separated into its elements, its carbon uniting with other elements to form various compounds, such as starch, sugar, woody fiber, etc., the oxygen being largely returned to the air as free or uncombined oxygen.

Oxygen, next to carbon, is the most abundant element found in plants, and there are very few compounds occurring in plants which do not contain more or less oxygen. The chief function of oxygen is to supply the various compounds of plants with the needed portion of this material. Plants require oxygen about as much as do animals. Green plants can not flourish without a supply of oxygen. The absence of oxygen prevents the germination of seeds. Considerable quantities of oxygen are absorbed from the air by the opening buds of trees. More or less oxygen in the soil is necessary for the active life of roots. In the act of flowering, the absorption and chemical action of oxygen in the blossom is so marked, in some cases, as to develop sufficient heat to be measured by a thermometer.

Water (Hydrogen and Oxygen).—In the combination of oxygen with hydrogen in the form of water, these two elements perform important functions. In the first place, nearly all the hydrogen found in the different compounds of plants comes from water. More or less of the oxygen is also supplied this way. In addition to furnishing materials with which to build other compounds, water acts as a carrier within the plant in transferring from one part of the plant to another, as needed, the various products contained in the plant, just as the blood in the animal body carries to every portion the nutriment adapted to each organ and part.

Nitrogen.—The influence of nitrogen in its various forms upon plant growth is shown by at least three striking effects.

First. The growth of stems and leaves is greatly promoted, while that of buds and flowers is retarded. Ordinarily, most plants, at a certain period of growth, cease to produce new branches and foliage, or to increase those already formed, and commence to produce flowers and fruit, whereby the species may be perpetuated. If a plant is provided with as much available nitrogen as it can use just at the time it begins to flower, the formation of flowers may be checked while the activity of growth is transferred back to and renewed in stems and leaves, which take on a new vigor and multiply with remarkable luxuriance. Should flowers be produced under these circumstances, they are sterile and produce no seed.

Second. The next effect of nitrogen upon plants is to deepen the color of the foliage, which is a sign of increased vegetative activity and health.

Third. Another effect of nitrogen is to increase in a very marked degree the relative proportion of nitrogen in the plant. This is something which we cannot see with our eyes and which can be ascertained only by chemical analysis. The importance of this fact may not be readily apparent, but it becomes so, when we consider that much of the value of some foods depends upon the amount of nitrogen-compounds, that is, proteids, contained in them. For example, some samples of wheat may contain only eight per cent. of proteids, while others may contain twice this amount. This difference in composition makes a great difference in food value.

Phosphorus.—Experiments have shown that plants will die before reaching maturity, unless they have phosphoric acid compounds to feed upon. Phosphates appear to perform three distinct functions in plants.

First. Phosphorus compounds aid in the general nutrition of the plant by furnishing such quantities of phosphorus as are needed in building proteids and in forming other phosphorus plant compounds.

Second. Phosphorus affects the development of seeds and fruit. More phosphorus is found in the seeds than in any other portion of a plant. Plants do not come to maturity and so do not produce seeds, unless the plants can get phosphorus compounds to feed on. Owing to the intimate connection between phosphorus and seed formation, a liberal application of available phosphorus compounds to plants in the earlier stages of growth appears to hasten somewhat their maturity. In this respect, it acts upon plants in a manner opposite to nitrogen, whose presence in large amounts retards ripening.

Third. Certain forms of phosphates render the proteids sufficiently soluble to enable them to be carried from the growing parts of plants to the seeds, in which they accumulate in quantity.

Potassium compounds are instrumental in performing several different functions in the economy of plant life.

First. Potash compounds are essential to the formation and transference of starch in plants. Starch is known to be first formed in the leaves of plants, after which in some way it becomes soluble enough within the plant-cells to enable it to pass through the cell-walls gradually and later to be carried into the fruit, where it accumulates and changes back to its insoluble form. It is well established that potassium compounds are intimately connected with the formation of starch in the leaves and with its transference to the fruit. No other element can take the place of potassium in performing this work. For the carrying of starch a minute amount of calcium (lime) and chlorine appears to be needed in addition to the potassium.

Second. Potassium compounds are important because they exercise a marked influence upon the development of the woody parts of stems and the fleshy portions of fruit.

Third. We have already stated that the formation and transference of starch is more or less dependent upon potassium compounds present in the plant. Now, this formation of starch and transference to the fruit are preliminaries in the production of sugar, which contributes so much to human enjoyment.

Fourth. Potassium compounds are present in those plant juices, which are rather sour; in these cases, the potassium is combined as an acid salt with such acids as citric, malic, tartaric, oxalic and other acids.

Sulphur.—Plants must have sulphur in order to make proteids. Without sulphur, plants cannot produce such vegetable oils and characteristic flavors as those contained in onions, horseradish, turnips, mustard, etc.

Calcium forms a part of several compounds found in plants. Its chief function appears to be that of strengthening cell-walls. It is often found united with different acids forming calcium (or lime) salts. Thus, in beet leaves, we find the salt calcium oxalate. In what specific way it otherwise affects the growth of plants, we do not yet know definitely.

Chlorine.—The function of chlorine in connection with the development of plants is not satisfactorily settled. There are some reasons for believing that some of the compounds of chlorine, especially the potassium chloride (muriate of potash), are instrumental in transferring starch from the leaves, where it is formed, to the flower and fruit.

Silicon.—It is an unsettled question as to what silicon does in plant growth. Some have thought that its functions might be to give stiffness to slender stems in the case of such plants as grasses, sedges, etc., but there are some serious objections which interfere with the complete acceptance of such a proposition. Others claim, on good grounds, that silicon really performs no function in plant life, its common presence being an accident and not a necessity.

Iron is essential to the formation of the green coloring-matter of plants called chlorophyl. In the absence of iron, leaves lose their green color and become pale or white and no starch is formed.

Magnesium closely resembles calcium in many ways, but cannot replace it in plants. Magnesium appears to be associated with nitrogen in the formation of proteids; it also appears to have some effect upon the formation of the green coloring-matter or chlorophyl of plants.

5. The Relations of the Different Elements of Plant-Food to Soils.

General Composition and Origin of Soils.—Of the elements found in plants all but four come exclusively from the soil, as previously indicated. These have already been described, and we do not need to give further attention to them in this place. The soil-derived elements, though forming on an average less than five per cent. of the whole vegetable kingdom, are of the utmost interest and importance to the farmer; for, while the atmosphere is in itself entirely beyond his control, he can, through the medium of the soil, influence the amount of air-derived constituents taken up by plants.

Soils consist of decomposed and pulverized rocks mixed in varying proportions with organic matter called humus, formed by the decay of animal and vegetable substances. The principal part of the soil was once solid rock, and the first step toward the formation of soil was the powdering of the rock. The conversion of rocks into soil has been accomplished by means of various agencies, such as heat and frost, moving water and ice, chemical action of air and water, and the influence of animal and vegetable life. The value of a soil for agricultural purposes depends largely upon the original material from which it was made, and upon the state of fineness to which it has been reduced.

Soil-Particles.—The fineness of division required in a good agricultural soil is not easily realized. According to estimates reliably made, a single ounce of good soil contains many *thousand-millions* separate particles. If the surface of all the particles in one cubic foot of soil could be spread out in one continuous plane, they would cover an area of two or three acres; and it is to be kept in mind that this great spread of surface is accessible to the root systems of plants in each cubic foot of such soil.

One classification of soils is based upon the size of soil-particles. The particles of a soil may be separated into two general classes. The first is called "skeleton" and consists of particles coarser than one-fiftieth of an inch in diameter. The second class is called "fine earth" and consists of all except the "skeleton." In agricultural soils "skeleton" varies from five to twenty per cent.

The "fine earth" is divided into six grades of soil-particles, called (a) medium sand, (b) fine sand, (c) very fine sand, (d) silt, (e) fine silt, (f) clay.

Sand.—The term sand, used in connection with soil-particles, includes those particles whose size varies from one-fiftieth to one-five hundredth of an inch in diameter. These are sub-divided into three grades of sand. Soils characterized as sandy contain from five to fifteen per cent. of silt and clay, as pure sand would have no agricultural value. When mixed with clay, sand serves to diminish the compactness of the clay, making it more porous and permeable to air and water. Too large a proportion of sand renders soils too porous and open, so that they admit water, warmth, and air too freely and there results excessively rapid evaporation of soil moisture together with marked heating of the soil and a consequent premature ripening and burning of the crops.

Silt.—Soil-particles included under the term silt vary in size from one-five-hundredth to one-five-thousandth of an inch. The characteristics are intermediate between sand and clay. A silt soil is more permeable to water than clay but less so than a sandy soil.

Clay.—The word clay used in connection with soil-particles has reference only to the size of the particles without regard to chemical composition. It includes all soil-particles whose size is less than one-five-thousandth of an inch in diameter. Arable soils contain from three to fifty per cent. of clay. Used in its chemical sense, clay is the common name of a compound called aluminum silicate. Clay soils must be handled with great care. When worked in too wet condition, they are puddled and this condition prevents the proper drainage of surface water. Many clay soils are too compact, retaining water and not allowing plant roots to penetrate easily.

Humus.—The word humus means, in general, the organic matter in the soil formed by the decay of animal or vegetable materials. In this sense humus is a very variable substance, its composition depending upon the materials from which it is formed and upon the conditions of decomposition. For example, humus formed from saw-dust or leaves will differ very greatly from that produced by clover or cotton-seed meal. In appearance humus is brown or black. Leaf-mold, swamp-muck and peat are varieties of humus, differing in appearance according to the condition of their origin and formation.

It is known that animal or vegetable matter decaying in the soil, forms compounds of an acid character and these organic acids unite with lime, potassium and other constituents of the soil. Moreover, it is known that materials rich in nitrogen like meat scraps and cotton-seed meal produce humus that is not only rich in nitrogen but also has the power to unite with the potash and phosphoric acid of the soil, thus rendering them more available as plant food.

Humus is extremely valuable for the following reasons:

(*First.*) Humus absorbs water much more extensively than any other ingredient of the soil and thus promotes the water-holding and water-conserving power of the soil.

(*Second.*) Humus aids in the decomposition of the mineral matters of the soil, changing unavailable into available plant-food. Its action in rendering the potash and phosphoric acid of the soil available is of marked value.

(*Third*) Humus fixes ammonia in the soil, so as to prevent it from being carried off by rains. The ammonia thus fixed is held until it gradually undergoes conversion into nitrate nitrogen, when it is in condition for immediate use as plant-food.

(*Fourth.*) Humus improves the mechanical condition of heavy soils by making them lighter, more porous and less adhesive. It also is helpful on sandy soils, serving to bind together the loose particles of soil, enabling it to retain moisture and preventing excessive leaching of plant-food.

Need of Humus in Soils.—In soils under constant cropping, there is usually a gradual loss of humus, unless special means are employed to add humus-making materials to the soil. Peat and muck soils are apt to contain an excess of humus. Sandy soils are most apt to be deficient in humus. Clay soils lose their humus less rapidly than sandy soils under like conditions.

Supplying Humus to Soils.—Humus-forming materials may be furnished the soil in the following ways: By crop roots remaining in the soil, by plowing under green crops or stubble, by addition to soil of animal and vegetable materials, such as farm-manures, straw, refuse, cotton-seed meal, dried blood, etc. The value of humus as a direct source of plant-food and as a means of making available the insoluble potash and phosphoric acid of the soil varies according to the kind of material from which it comes. Humus from materials rich in nitrogen is more valuable than when containing less nitrogen. In supplying humus to soils, it should be remembered that the presence of lime in the soil is one of the conditions required for the production of humus of value.

Amount of Plant-food in Soil.—The proportion of plant-food even in a fertile soil is comparatively small. One thousand pounds of a good soil may contain:

Phosphoric acid, 1½ pounds.
Nitrogen, 1½ pounds.
Potash, 2 pounds.

Some soils contain larger quantities than these. But when we consider the total amount of plant-food in one acre of soil, the amounts appear large.

While the weight of soil in an acre of different kinds of land varies, we may take the average weight of dry soil in one acre to the depth of nine inches as approximating about 3,000,000 to 3,500,000 pounds. One acre of soil containing the proportions of plant-food given above would, therefore, contain the following aggregate amounts:

Nitrogen, 4,500 pounds.
Phosphoric acid, 4,500 pounds.
Potash, 6,000 pounds.

A large portion of the plant-food in the soil is not available. The character of the soil affects very considerably the available condition of the plant-food. For example, a sandy soil is rendered fertile by a smaller amount of plant-food than is a clay soil, owing, in part to the different condition in which the mineral food exists in the sandy soil. The insoluble condition of plant-food in the soil prevents its rapid loss by leaching.

Loss of Fertilizing Constituents from the Soil.—Without going into a detailed explanation in regard to the causes, we will consider briefly the extent to which the three chief forms of plant-food are liable to be lost from soils. In general, it may be said that when plant-food materials come into contact with a soil, some kind of chemical combination is apt to take place between the constituents of the soil and the fertilizer. On this account, plant-food when applied in soluble forms may combine with the soil to form compounds which are less soluble, but still sufficiently soluble to be utilized as food by plants.

(*a*) *Nitrogen Compounds.*—Since ammonia compounds and nitrates dissolve easily in water, is there not danger of their being carried away in drainage water from the upper soil out of reach of the plants? Experiments have been made to settle the question, and results indicate that *ammonia* compounds are largely retained until they are changed into nitrates. *Nitrates are apt to be washed out* in drainage water *and lost in the case of bare fallow land*, the loss amounting to nearly forty pounds of nitrogen an acre in average seasons. The quantity of nitrogen lost in this way is very much greater than is used by many crops, and is, moreover, in the most available form for plant-food. However, when soil is covered with vegetation there is little or no loss, for the reason that roots of growing plants absorb nitrate nitrogen very rapidly.

Some nitrogen may be lost also from organic matter undergoing decay in the soil, escaping into the air as free nitrogen. This has been shown to be very large in case of soils rich in vegetable matter when improperly managed.

(*b*) *Phosphoric Acid in Phosphates.*—The ordinary form of calcium phosphate being insoluble in water, is not, to any appreciable extent, removed from the soil by the drainage water. The soluble form of calcium phosphate would probably be lost to some extent in drainage water, were it not for the fact that it is quickly changed in the soil to the "reverted" or less soluble form and, in this "reverted" condition, the phosphate is not apt to be carried away in drainage water. In some soils, heavy clay soils, for example, soluble phosphates not used the first season by plants may enter into such insoluble combination with the soil as to become unavailable. On such soils it is, therefore, better to apply phosphates each year in quantities suitable for a single crop, rather than attempt to make one heavy application to cover a period of years.

(*c*) *Potash in Potassium Compounds* is not apt to be lost to any extent in drainage waters, since most soils have the power of changing soluble forms of potash into forms less soluble, which are gradually redissolved and given up for the use of plants.

In addition to the preceding statements, it may be said, in general, that loss of plant-food is greatest in sandy soils; the coarser the sand, the greater the loss, other conditions being the same. Clay and humus have very marked power in retaining plant-food.

Relations of Plants and Soils.—We have seen that a very small part of the soil furnishes the most important constituents of plant-food. The soil also performs other functions than furnishing plant-food. We can summarize as follows the general offices which the soil fulfills in its relation to plants:

First. The soil acts as a mechanical support for plants; the roots of the plants penetrate the soil downwards and sideways, and brace the plant firmly to its upright position.

Second. The soil furnishes directly all the soil-derived elements used by the plant, and is thus immediately connected with the nutrition of plants. In addition, the soil serves as a medium for conveying to the plant a considerable portion of the air-derived elements.

Third. The soil contributes to the development of plants by modifying and storing the heat of the sun, by regulating supplies of food, and, in various ways, by securing those conditions which must be present and unite to produce the fully developed plant.

Fourth. The soil acts like a sponge to hold water for the use of plants.

Analysis of Soils.—The value of chemical analysis for ascertaining the plant-food needs of a soil is liable to be overestimated. Soil analysis has not yet reached such a stage of perfection that its results can always be interpreted correctly. It gives definite results when it shows the complete absence of one or more necessary plant-food constituents. Its chief weakness lies in the present inability to estimate accurately the amount of *available* plant-food in a soil. It is only under unusual conditions that a farmer will be justified in having soil analyzed in order to learn its plant-food requirements. There are other and more certain means to use for gaining this knowledge, which the farmer can apply to best advantage, as will be indicated later.

6. The Relations of Micro-Organisms to Soils and to Plant Food.

Nitrification and its Importance.—The absolute necessity of nitrogen as food for plants has been mentioned and it has also been stated that plants require this nitrogen to be supplied to them in the form of nitric acid or nitrate compounds. A plant cannot feed directly upon the nitrogen of the air, or upon the nitrogen contained in ammonia or vegetable or animal matter. All these forms of nitrogen must first be changed into nitrate nitrogen, and the work of bringing about this change is accomplished by fermentation processes caused by several different micro-organisms or germs, constituting a chain of workers in a simple division of labor. The organic nitrogen of dried blood, bone, cottonseed-meal, stable-manure, etc., is changed into *ammonia* by one set of workers; the ammonia is taken by another set and carried along to another stage called *nitrous acid*, and this in turn is changed into *nitric* nitrogen by a third set of works. The general process by which nitrogen in other forms is changed into nitrate nitrogen is commonly spoken of as *nitrification.* The importance of the work done by these different micro-organisms working together can be appreciated, when we realize that without their work no plants could be grown and all forms of vegetable and animal life would perish.

These micro-organisms are the smallest imaginable kinds of plants and we cannot see them singly by the unaided eye. They are commonly called germs. Another name for many of them is *bacteria.*

Number of Micro-Organisms in Soil.—The number of different kinds of micro-organisms in the upper portion of ordinary cultivated soils varies roughly from one to fifty millions to the ounce. The number diminishes rapidly below a depth of thirty inches. At six feet below they nearly disappear. The number is greater in cultivated than in uncultivated soils, in well fertilized soils than in unfertilized soils, in soils rich in humus than in light sandy soils. The number is greater in summer than in winter. The addition of organic matter like stable-manure greatly increases the number of germs. As a rule, an increase in the amount of available plant-food in the soil follows an increase in the number of micro-organisms or bacteria. Such increase can be secured by thorough cultivation, liberal manuring, and the use of leguminous plants as green-manures.

Conditions Required for Nitrification.—The activity of the micro-organisms which prepare unavailable forms of nitrogen for the use of plants by converting them into nitrate nitrogen is hastened by certain favorable conditions and retarded by unfavorable ones. The principal conditions that have to be considered in relation to the growth of these micro-organisms will now be mentioned.

(*a*) *The Presence of Moisture.*—In a dry soil nitrification does not take place. Hence, in periods of drouth this important process stops in the upper portions of the soil. In a wet soil, on the other hand, where water is stagnant, this process does not take place actively.

(*b*) *Food Requirements of Nitrifying Organisms.*—The organic matter of the soil forms the main supply of organic food for these organisms. It is possible to have so much organic matter present that the organisms will stop growing, as in a manure pile. It is also necessary that certain forms of mineral matter be present, chief among which is a supply of phosphoric acid compounds.

(*c*) *Oxygen Required.*—Nitrifying organisms cannot flourish without a supply of air. Water-saturated soils prevent the process by shutting off the air supply. The stirring and pulverizing of the soil by cultivation greatly promotes the change into nitrate nitrogen because it brings the oxygen of the air into closer contact with the nitrifying ferments.

(*d*) *Temperature of Soil.*—The nitrifying organisms work most rapidly between the temperatures of 54 degrees and 99 degrees Fahrenheit. The process may take place as low as 37 degrees Fahrenheit, and as high as 120 degrees Fahrenheit. In this latitude nitrification stops during the winter, while in warm climates it continues during the whole year.

(*e*) *Some Material like Lime Necessary.*—The presence of some mineral compound in the soil that will prevent acid condition of soil is necessary, since the action of these micro-organisms is checked by acids. The lime compounds are the most available ones. Hence, it is important to lime soils occasionally, in order that the preparation of nitrate nitrogen can take place.

Conversion of Atmospheric Nitrogen into Plant-Food by Micro-organisms.—Another most important work done by certain micro-organisms is the production of nitrogenous plant-food from the nitrogen of the air. Certain plants, known as leguminous, such as clover, peas, beans, etc., have been proved to utilize atmospheric nitrogen as a source of food supply. They are able to accomplish this through the action of certain germs. If the roots of a healthy clover plant are examined, there will be found on them little round bunches or tubercles, varying from the size of a shot to that of a pea. These have been found to be colonies containing enormous numbers of germs having the power to assimilate atmospheric nitrogen. They are accompanied by other germs which change the nitrogen, thus taken from the air, into nitrate-nitrogen, which the plant uses as food.

Loss of Nitrogen Through Micro-organisms.—The soil contains certain kinds of germs which have a power opposite to that of nitrifying germs; that is, they change nitrates back through different forms into some form that is likely to escape into the air and be lost as plant-food. This process is known as *denitrification*, which is simply the destruction of nitrates as plant-food. These germs are abundant also in straw and in stable-manure. It is important to know the conditions under which this destructive process takes place and thus learn to avoid such losses.

(*a*) *Absence of Air* is favorable to the destruction of nitrates. Too much water in the soil has the effect of shutting off the supply of air and thus the denitrifying organisms are enabled to do their injurious work. Good drainage and thorough tillage will overcome this condition.

(*b*) *An Excessive Amount of Humus* in the soil favors the destruction of nitrate compounds. This is a condition not often met in common farm practice.

(*c*) *Loss of Nitrogen from Stable-Manure.*—Those organisms that feed upon nitrate are very abundant in stable-manure and straw. These losses can be prevented by using preservatives in the manure as described later, and also by using bedding material free from decomposable organic matter.

PART II.

DESCRIPTION OF MATERIALS USED AS FERTILIZERS.

1. Forms of Plant-Food Essential to Fertilizers.

In the absence of iron in the soil, plants turn yellow and cease to grow; other elements, as magesium, sulphur, etc., are essential to the complete development of a plant. But these elements are used by plants in very small quantities, and, moreover, they occur abundantly everywhere in soils, as already indicated. Therefore, it is rarely necessary to supply these elements artificially to soils, and we do not need to consider them in connection with fertilizers. The elements of plant-food which experience most often shows to be lacking in soils are these four:

Nitrogen, *Potassium* (contained in potash compounds,) *Phosphorus* (contained in phosphoric acid compouds or phosphates), and in special cases, *Calcium* (contained in lime compounds).

2. Stimulant or Indirect Fertilizers.

A Stimulant or Indirect Fertilizer is one which does not in itself furnish directly to the soil any needed plant-food, but whose chief value depends upon the power it possesses of changing unavailable into available forms of plant-food. The stimulant or indirect fertilizers which have been most commonly employed are lime, gypsum and common salt.

Gypsum or Land Plaster, known also as calcium sulphate or sulphate of lime, has been much used in fertilizing crops. Its value is due to its action as an *indirect* fertilizer. There has been much difference of opinion as to the manner in which gypsum acts. Probably it acts in at least three different ways, as follows:

First. It has the power to form compounds with ammonia, in which the ammonia is no longer in danger of loss by evaporation. This power of fixing ammonia is probably of little value when plaster is applied to the surface of the soil, but it may be of much value when scattered over a heap of fermenting manure, and moistened with water, when it will retain the ammonia which would otherwise escape. For the same reason, plaster is useful to distribute about stables, so that it may mix with the manure.

Second. It has been shown that gypsum in some manner aids the process of nitrification, by which ammonia and the nitrogen of organic matter are converted into nitrate nitrogen.

Third. Gypsum acts upon the insoluble forms of potash and some other elements of plant-food, converting them into soluble and available forms which plants can readily take up and use. This is probably the most important effect of plaster as an indirect fertilizer.

In whatever way gypsum may act, it is well established that it is of value when applied on certain soils to certain crops, such as clover, peas, lucern and similar plants. Nearly all fertilizers containing soluble phosphoric acid contain gypsum, as will be explained later.

The more common sources of supply of land-plaster are Nova Scotia and Central New York, the latter being less pure.

Quicklime.—Quicklime or burnt lime or calcium oxide, commonly called lime, is known to be valuable as an indirect fertilizer. It produces changes in both the physical and the chemical character of soils. It changes the mechanical condition of soils by loosening heavy clay soils and also by holding together and giving body to light sandy soils. Freshly burned lime acts chemically upon soils by decomposing vegetable and mineral matter already present in the soil and changing them into forms which are available as food for the plant. Thus, lime acts upon insoluble mineral substances containing potash, soda, etc., and converts them into soluble forms which plants can use. Lime aids in the decomposition of animal and vegetable matter, such as vegetable mold, stable manure, etc., and tends to convert them into available plant-food. Lime also neutralizes the acidity or "sourness" of soils. We shall later consider the conditions under which lime can be used to advantage and also the methods of its use.

Gas-Lime.—Quicklime is used in gas works for the purpose of removing impurities from the gas. In the operation the lime becomes slaked and takes up various materials that are injurious to plant-life; however, these impurities, on exposure to air, are changed into harmless forms. In using gas-lime on soils, it should either be exposed to the air sometime previous to applying to soil or should be applied some weeks or even months before putting the crop in the soil. Gas lime may contain a small amount of nitrogen.

Common Salt has an indirect fertilizing value which is due to the fact that it has the power of changing unavailable forms of plant-food into available forms, and increasing the power of soils to absorb water. Salt probably furnishes no needed form of plant-food. All the salt that can probably be utilized to advantage is contained as impurities in some of the potash salts, such as kainit.

Danger in using Stimulant Fertilizers.—It should be kept in mind that these stimulant fertilizers are not used for the plant-food contained in them; hence, as used, they do not furnish needed plant-food. The chief value of their use lies in the fact that they can change unavailable into available forms of plant-food. It can readily be seen that, when stimulant fertilizers are used exclusively for a term of years, the soil each year loses nitrogen, potassium and phosphorus compounds, which are not replaced. The inevitable result of such treatment is the exhaustion of these important food constituents from the soil. This affords an explanation of the question often raised now as to why the application of land-plaster does not give such results in crop yields at present as in former days. When land-plaster was the only fertilizing material added to soils for years in succession, it was possible to produce increased crops, so long as there were in the soil enough compounds of nitrogen, potassium and phosphorus to be rendered available by the action of the land-plaster. When, therefore, these forms of plant-food were largely removed, there was nothing for the land-plaster to act upon, in order to increase the supply of available food material. The land-plaster furnished no needed food but simply helped the crops to use up more rapidly the store of plant-food present in the soil.

3. Nutritive or Direct Fertilizing Materials.

Nutritive or Direct Fertilizers contain forms of plant-food, which contribute directly to the growth and substance of plants. Such materials may contain either nitrogen or potash or phosphoric acid compounds, or any two, or all three of these forms of nutriment. We shall consider these various materials under the following heads:

(a) Commercial fertilizing materials containing nitrogen compounds.
(b) Commercial fertilizing materials containing phosphoric acid compounds.
(c) Commercial fertilizing materials containing potash compounds.
(d) Farm-produced fertilizing materials.

This division is not sharply defined, since one material may contain more than one form of nutriment; however, in most cases, each kind of material contains some one of the three forms of plant-food in much larger proportions than any other form. Owing to the value of farm-produced manures and to the importance of calling special attention to their value, we treat this subject under a separate head in connection with the forms of materials used in commercial fertilizers.

(a) Fertilizing Materials Containing Nitrogen Compounds.

The various materials which are used to furnish nitrogen in commercial fertilizers are derived from three general sources, which we can indicate as follows:

(1) Mineral nitrogen compounds.
(2) Vegetable nitrogen compounds.
(3) Animal nitrogen compounds.

(1) *Commercial Fertilizing Materials Containing Mineral Nitrogen Compounds.*

The forms of mineral compounds containing nitrogen, most commonly found in the market, are *nitrate of soda* and *sulphate of ammonia.*

Nitrate of Soda, known also as "Chili saltpeter," is found in large deposits which have been formed in the rainless regions of Chili and Peru. As it is mined, the nitrate of soda is quite impure, the chief impurity being common salt. Before being sent to market, it is purified, and the form in which farmers purchase it generally contains from 95 to 96 per cent. of real nitrate of soda. Stated in another way, 100 pounds of good commercial nitrate of soda contain from 15½ to 16 pounds of nitrogen.

Sulphate of Ammonia is formed from waste materials produced in the manufacture of illuminating gas. This is the most highly concentrated form of nitrogen commonly found in the market. One hundred pounds of sulphate of ammonia contain about 25 pounds of ammonia, which is equivalent to about 20½ pounds of nitrogen.

(2) *Commercial Fertilizing Materials Containing Vegetable Nitrogen Compounds.*

While nitrogen may be supplied by many forms of vegetable matter, only a few substances of this kind are used in commercial fertilizers, chief of which are *cottonseed-meal*, *castor-bean pomace*, *linseed-meal*, *and tobacco-stems.*

Cottonseed-Meal is the product formed by removing the oil from the seed by pressure, after which the material is dried and ground. It has been used at the South mainly for fertilizing purposes. One ton of cottonseed-meal contains about 140 pounds of nitrogen, 60 pounds of phosphoric acid and 40 pounds of potash. It is valued highly as a food for cattle, and, when thus fed, practically all of the fertilizing value is recovered in the manure. When it can be purchased at a moderate price, it makes a valuable fertilizer to be applied directly to the soil. The hulls of the cottonseed also possess considerable fertilizing value.

Castor-Bean Pomace is a by-product of castor-oil factories; it is made by about the same process as that used in producing cottonseed-meal. As a rule, it has less fertilizing value than cottonseed-meal, one ton containing about 110 pounds of nitrogen, 40 pounds of phosphoric acid and 20 pounds of potash.

Linseed-Meal is the product left after removing oil from flax seed. One ton of linseed-meal contains about 110 pounds of nitrogen, 37 pounds of phosphoric acid, and 28 pounds of potash. Its extensive use as a cattle food makes it too high priced for common use as a source of nitrogen for fertilizers.

(3) *Commercial Fertilizing Materials Containing Animal Nitrogen Compounds.*

Probably the larger proportion of the nitrogen occurring in commercial fertilizers is at present furnished by animal matter in one form or another. This material comes mainly from slaughter houses, rendering works and fish-oil factories. The following list contains most of the substances of animal origin commonly used: *Azotin or am-*

monite, *dried blood*, *dried fish*, *fish scraps*, *garbage tankage*, *ground fish*, *hair*, *hoof-meal*, *horn-dust*, *leather-meal*, *nitrogenous guanos*, *tankage*, *wool-waste*, *etc.*

Azotin or Ammonite consists of dried and ground meat, tendons, membranes, etc., from which fat has been extracted. It usually contains over 10 per cent. of nitrogen along with 3 or 4 per cent. of phosphoric acid.

Dried Blood consists of blood obtained from slaughtered animals; it is prepared for market by evaporating, drying and grinding. The color varies with the degree of heat employed in drying, ranging from red to black. Red blood is of higher grade than black blood. The red dried blood contains 13 to 15 per cent. of nitrogen with very little phosphoric acid. Black dried blood contains from 6 to 12 per cent. of nitrogen and usually some phosphoric acid. It is this lower grade of dried blood that is most commonly employed in the manufacture of fertilizers.

Dried Fish, Fish-Scraps, and Ground Fish consist of refuse from fish-oil works, and fish-canning factories. The material obtained from fish-oil works is the residue left after the extraction of oil; it is prepared for market by drying and grinding. It is quite uniform in composition, containing 7 to 8 per cent. of nitrogen and as much or more phosphoric acid. The product obtained from canning works consists of skin, bones, etc., of fish and is very variable in composition.

Tankage is slaughter-house refuse made up of miscellaneous refuse matter such as bone, tendons, hair, hides, horns, hoofs, etc. Two kinds of tankage are known in the market. One kind is known as concentrated tankage and is made by evaporating some of the fluids rich in nitrogen. This form of tankage contains 10 to 12 per cent. of nitrogen with only a little phosphoric acid. The second kind is known as crushed tankage and consists of varying quantities of different parts of animal carcasses. As a rule, the fat and gelatin are first removed by straining or boiling and the residue is dried and ground. Sometimes a little slaked lime is added to prevent loss of nitrogen by rapid fermentation. Crushed tankage varies greatly in composition, the nitrogen ranging from 4 to 9 per cent. and the phosphoric acid from 3 to 12 per cent.

Garbage-Tankage is material obtained by drying city garbage. Sometimes it is partially charred. Its composition varies greatly, containing nitrogen, phosphoric acid, and potash, but in small proportions. It is usually richer in nitrogen than in any other plant-food. It is a low-grade fertilizing material. Both its composition and value as plant-food are variable and uncertain.

Hair is obtained from slaughter-houses; it is often mixed with dried blood and other forms of animal matter. It contains about 15 per cent. of nitrogen. Wool-waste is much like hair in composition.

Hoof-Meal and Horn-Dust are by-products containing 10 to 15 per cent. of nitrogen and about 2 per cent. of phosphoric acid. They are sometimes treated with superheated steam or with sulphuric acid, the treatment rendering the nitrogen compounds more readily available.

Leather-Scraps and Leather-Meal are waste products of various factories. When treated with superheated steam and dried or roasted, they can be very finely ground. Roasted, finely ground leather is used to adulterate dried blood, having much the same appearance.

Nitrogenous Guanos are formed in warm dry regions. Peruvian guano is rich in nitrogen, containing 7 per cent. or more, mainly in the form of sulphate of ammonia. Guanos of this kind have largely disappeared from the market.

The following table gives the approximate quantities of nitrogen contained in various fertilizing materials:

Table Giving Approximate Amount of Nitrogen in Fertilizing Material.

Materials Containing Nitrogen.	Average per cent. of nitrogen.	Pounds of nitrogen in 2000 pounds of material.
(1) *Mineral materials.*		
Nitrate of potash,	13 to 14	260 to 280
Nitrate of soda,	15½ to 16	310 to 320
Sulphate of ammonia,	19 to 20½	380 to 410
(2) *Vegetable materials.*		
Cotton-seed meal,	6 to 7	120 to 140
Castor bean pomace,	5 to 6	100 to 120
Linseed meal,	5 to 6	100 to 120
Tobacco stems,	2 to 2½	40 to 50
(3) *Animal materials.*		
Azotin, ammonite,	10 to 12	200 to 240
Dried blood, red,	13 to 15	260 to 300
Dried blood, black,	6 to 12	120 to 240
Dried fish,	7 to 8	140 to 160
Hair,	14 to 16	280 to 320
Hoof meal, horn dust,	10 to 15	200 to 300
Leather scraps, leather meal,	7 to 8	140 to 160
Meat scraps,	10 to 12	200 to 240
Nitrogenous guanos,	7 to 8	140 to 160
Oleomargarine refuse,	10 to 12	200 to 240
Tankage, concentrated,	10 to 12	200 to 240
Tankage, crushed,	4 to 9	80 to 180
Tankage, garbage,	1 to 2	20 to 40
Wool waste,	5 to 6	100 to 120

(*b*) *Fertilizing Materials Containing Phosphoric Acid Compounds.*

Phosphoric acid is generally found in combination with lime (calcium), forming four different compounds, viz:

(1) Insoluble phosphate of lime, or tri-calcium phosphate.
(2) Soluble phosphate of lime, or mono-calcium phosphate.
(3) Reverted phosphate of lime, or di-calcium phosphate.
(4) Tetra-calcium phosphate.

(1) *Insoluble Phosphate of Lime.*

This is known under several other names, as "insoluble calcium phosphate," "normal calcium phosphate," "tri-calcium phosphate," "bone phosphate of lime," etc.

This form of calcium phosphate is called *insoluble* because it does not dissolve in water.

It is found in nature in large quantities in several minerals, which will be noticed later. It also constitutes about 85 per cent. of the ash or inorganic matter of bones. It is also contained in the excrement of animals, as in guano, etc.

Insoluble phosphate of lime is found everywhere in the soil. However, in this form, calcium phosphate has the least value for the farmer, because it is not easily dissolved and can not, therefore, be taken up and used by plants, except very slowly. To make the insoluble phosphate available for plants so that they can take it up, the insoluble phosphate must be converted into some form which is soluble, that is, which dissolves in water. This can be done by treating it with sulphuric acid (oil of vitriol).

(2) *Soluble Phosphate of Lime.*

This is known under several other names as "acid phosphate of lime," "acid calcium phosphate," "acid phosphate," "superphosphate of lime," "superphosphate," "mono-calcium phosphate," etc. It is not found naturally occurring.

As indicated above, the soluble calcium phosphate is made by treating insoluble calcium phosphate with sulphuric acid. By this treatment, a portion of the calcium is removed from the phosphate and unites with the sulphuric acid, forming sulphate of lime or gypsum in addition to the soluble phosphate. This mixture of the soluble phosphate and gypsum is known as "superphosphate of lime." The phosphate in this form, being easily soluble in water, can be readily taken up by plants and is, therefore, of great value as a fertilizer. The sulphate of lime is also known to have value as an indirect fertilizer. In plain superphosphate of lime, there are generally formed about 116 pounds of water-free sulphate of lime (equivalent to 147 pounds of gypsum) for each 100 pounds of soluble phosphate of lime. The value of superphosphates depends upon the amount of soluble phosphate contained in them. Soluble phosphate of lime whatever its source whether bone or rock is one and the same chemical compound and as such has the same value as plant-food.

(3) *Reverted Phosphate of Lime.*

Reverted phosphate of lime is known also as "reverted calcium phosphate," "precipitated phosphate of lime," "di-calcium phosphate," "citrate-soluble phosphate," etc.

When soluble phosphate of lime is allowed to stand for sometime, it will happen under certain conditions that some of the soluble phosphate is changed into a less soluble form of phosphate. This is not the same form as ordinary insoluble calcium phosphate above described; for a reverted phosphate, while insoluble in water, can be readily dissolved by weak acids or by water containing carbonic acid or salts of ammonia. Since the soil and plant roots generally contain acids sufficiently strong to dissolve reverted phosphates, phosphoric acid in this form is generally regarded as very nearly equal to soluble phosphates in value as a fertilizer. The term "reverted" was introduced to express the fact that the phosphoric acid in this form had once been soluble in water but that it had "reverted" or "gone back" to a form insoluble in water.

The reverted form of phosphoric acid is often found in small quantities in connection with insoluble phosphates, and in larger amounts, in guanos; it is also found to a considerable extent in bones and other forms of organic matter.

(4) *Tetra-calcium Phosphate.*

Tetra-calcium phosphate is a form of phosphate of lime found in phosphate slags. It contains more lime in proportion to phosphoric acid than any other form of phosphate. While it is insoluble in water, it has been found to be more available as plant-food than insoluble phosphate of lime.

Summary.—Of the forms of phosphate of lime which are used as food for plants, we have

First, The ordinary *insoluble* phosphate of lime, which can be changed by treatment with sulphuric acid into

Second, The *soluble* phosphate of lime, and this, on standing, may, under certain conditions, undergo change, forming

Third, The *reverted* phosphate of lime, which is insoluble in pure water but soluble in the acids of the soil and plants and in water containing carbon dioxide.

The soluble and reverted forms of phosphoric acid, taken together, are called *available* phosphoric acid.

Chemical Differences of the Four Phosphates of Lime.

	Calcium—per cent.	Phosphorus — per cent.	Oxygen—per cent.	Hydrogen — per cent.
Insoluble phosphate of lime, Insoluble calcium phosphate, Normal calcium phosphate, Tri-calcium phosphate, Bone phosphate of lime, etc.,	38.7	20.0	41.3	0
Soluble phosphate of lime, Acid phosphate of lime, Superphosphate of lime, Mono-calcium phosphate, Acid calcium phosphate, etc.,	17.1	26.5	54.7	1.7
Reverted calcium phosphate, Precipitated phosphate of lime,	29.4	22.80	47.0	0.8
Tetra-calcium phosphate,	43.7	17.0	39.3	0

We notice the following points of difference in composition:

First. The *insoluble phosphate of calcium* contains the second largest amount of calcium, the second smallest amount of phosphorus, the second smallest amount of oxygen and no hydrogen.

Second. The *soluble phosphate of calcium* contains the smallest amount of calcium and the largest amount of phosphorus, oxygen and hydrogen.

Third. The *reverted calcium phosphate* contains amounts of calcium, phosphorus, oxygen and hydrogen which are intermediate between the two forms preceding.

Fourth. The *tetra-calcium phosphate* contains the largest amount of calcium, the smallest amounts of phosphorus and oxygen and no hydrogen.

With regard to phosphorus, which is the most valuable element in these phosphates of lime, the soluble phosphate of lime contains most of this element; the tetra-calcium phosphate of lime the least; and the reverted phosphate is second in regard to the amount of phosphorus contained in it.

Having called attention to the different kinds of compounds in which phosphoric is found, we are now prepared to consider more intelligently the different materials in which the phosphoric acid compounds of commerce are supplied for fertilizers. The materials which furnish the greatest proportion of phosphoric acid used in making fertilizers are the following: *Bones*, *bone-ash*, *bone-black*, *bone-meal*, *fish*, *phosphatic guano*, *rock-phosphate*, *superphosphates*, *Thomas slag*, *vegetable matter*, *etc.*

Bones.—Bones consist of two quite different kinds of material, in addition to water. The hard portion consists mostly of phosphate of lime, and constitutes from one-half to three-fifths of the weight of the bone. The remaining portion consists largely of a soft, flesh-like substance called ossein, or, more commonly, gelatin, together with more or less fat. It is distributed throughout the entire mass of bone and is rich in nitrogen. When bones are burned, the nitrogenous matter is driven off and only the mineral portion or phosphate of lime remains. The amount of nitrogen and phosphate of lime in bones varies with the kind of bone and also with the manner in which it is treated. Bones of different kinds of animals vary in composition and also different bones in the same animal. Age affects composition. The bones of young animals usually contain more nitrogen and less phosphate of lime, the reverse being true of older animals. As bones come into market for use as fertilizers, their variation of composition is due more to the manner in which they are treated than to differences of composition originally existing in the bones. We find in the market the following forms of bone as the common ones: Raw bone, bone-meal, steamed bone, and bone tankage.

Raw Bone.—By raw bone is understood bones that have been ground in their natural state without previous treatment, such as steaming, boiling, etc. Raw bone contains the fat naturally present in bones and this is objectionable, because it makes grinding more difficult and delays the decomposition of the bone in the soil, while fat itself has no value as plant-food. Good raw bone should contain 4 to 5 per cent. of nitrogen and 20 to 25 per cent. of phosphoric acid, equivalent to 45 to 55 per cent. of phosphate of lime.

Bone-Meal goes under various names, such as ground bone, bone-flour, bone-dust, fine bone, etc. These terms are supposed to refer to fineness of division rather than to composition. They are more commonly used of steamed than of raw bone-meal. The fineness of the bone affects its value; the finer the meal, the more readily available is it as plant-food. On account of the increased demand for bones for various purposes, and on account of their increasing value, there is considerable *tendency to adulterate bone-meal* with such substances as lime, gypsum, coal-ashes, ground oyster-shells, ground rock-phosphate, etc.

The composition of bone-meal varies, according to its manner of preparation. Bone-meal from raw-bones has the composition given above for raw bones, while bone-meal from steamed bone will contain less nitrogen and more phosphate of lime.

Steamed Bone.—Raw bones are treated under pressure by steam and by this means the ossein and fat are removed, the ossein being used chiefly for making glue and gelatin and the fat for making soap. The bones after this treatment are very brittle and, when dry, can easily be ground fine. The composition of steamed bone depends upon the thoroughness and extent of steaming or boiling. Bone from glue factories averages about 1.5 per cent. of nitrogen and 29 per cent. of phosphoric acid.

In some cases, the fat alone is extrated from bones by some solvent like petroleum or benzine, which removes none of the nitrogen. Such bone may contain as much as 6 per cent. of nitrogen with 20 per cent. of phosphoric acid.

The thorough steaming of bone appears to change the nature of the nitrogen-compounds or perhaps the mechanical condition of the bone in such a way as to permit more rapid decomposition in the soil than in case of raw bone. The presence of easily decaying nitrogen compounds in bone hastens, in the process of decomposition, to render soluble more or less of the insoluble phosphate.

Bone-Tankage.—While tankage is rich in nitrogen, some grades contain an abundance of phosphoric acid. Several distinct grades of tankage are now recognized, varying in phosphoric acid content from about 6 to 20 per cent. The higher grades are nearly like bone in their proportion of phosphoric acid. The higher the phosphoric acid in tankage, the lower is the nitrogen content. As previously stated, tankage is made from residues obtained from boiling refuse animal matter, heads, feet, etc. Hence the phosphoric acid of tankage may be regarded as having the same agricultural value as the phosphoric acid of steamed bone having the same degree of fineness.

Bone-Ash.—As the name implies, bone-ash is made simply by burning bones in the open air. The nitrogen is, of course, driven off and lost in burning, and the chief constituent is insoluble calcium phosphate, equivalent to 30 to 35 or more per cent. of phosphoric acid.

Bone-Black, known also as bone-charcoal and animal charcoal, is extensively used in refining sugar. After it has been used several times, portions become useless for refining purposes and are then sold as fertilizer. Bone-black is made by heating bones in closed vessels, the air being excluded. By heating bones in this manner, the fat, water, and nitrogen are removed from the bones; and the bone-black remaining consists mainly of insoluble calcium phosphate and carbon or charcoal. The presence of the carbon hinders the decomposition of the phosphate, so that it is, in this form, not readily available as food for plants. Good bone-black may contain 30 or more per cent. of phosphoric acid.

Fish.—Phosphoric acid is contained in fish and fish-scrap to the extent of 7 or 8 per cent. In many cases the fish is acidulated with sulphuric acid and its phosphoric acid is thus nearly all rendered available.

Phosphatic Guanos or Rock-Guanos.—Guanos generally consist chiefly of the dung of sea-fowls, though the term is applied to other animal products. They are generally found in beds resembling earthy deposits. The guanos which are called phosphatic contain little or no nitrogen. Their phosphoric acid is generally in the form of insoluble phosphate of lime, iron and alumnia. These guanos come mainly from certain islands in the Pacific ocean, and from Caribbean sea and West India islands. The amount of phosphoric acid in different guanos is very variable, ranging from below 15 to over 30 per cent.

Rock-Phosphates or mineral phosphates are known under several different names, which generally designate the localities from which they come, as South Carolina Rock, Florida Rock, Tennessee Rock, West India Rock, etc. Other forms of mineral phosphates are known under the names of Apatite, Coprolite and Phosphorite, which are found in various places in America and Europe, and some of which are used in making commercial fertilizers. However, the greatest source of supply of phosphoric acid is the phosphate rock of our Southern States. The rock-phosphates are extensively used in making superphosphates. When ground to a very fine flour-like powder, rock-phosphates are called "floats." Rock-phosphates contain usually from 20 to 30 per cent. of phosphoric acid, and some as much as 35 or 40 per cent.

Superphosphates are known under several different names, such as acid phosphate, dissolved bone, dissolved rock, dissolved bone-black, etc. Superphosphates are formed by treating some form of insoluble phosphate of lime, as rock-phosphate, bone, bone ash, etc., with sulphuric acid. With high grade material, equal parts of sulphuric acid and rock phosphate are used in dissolving the insoluble phosphate of lime. By this treatment there is formed a mixture of soluble phosphate of lime and gypsum (sulphate of lime) in which there are about one and one-half pounds of gypsum for each pound of soluble phosphate. Owing to their comparative cheapness and abundance, rock-phosphates are more often used in making superphosphates than bones, bone-ash or bone-black. The value of a superphosphate depends upon the amount of soluble phosphate of lime present in it together with the amount of reverted phosphate of lime. The amount of soluble phosphoric acid compounds in superphosphates varies with the kind of phosphate used in making superphosphates, and also with other conditions which we need not mention here. Good quality of dissolved bone contains 12 to 18 per cent. of soluble phosphoric acid. Dissolved bone-black contains from below 15 to 17 per cent. of soluble phosphoric acid. Superphosphate made from rock-phosphate may contain from 12 to 18 per cent. of soluble phosphoric acid.

"Double superphosphate" is a name applied to a concentrated form of soluble phosphoric acid. It is chiefly manufactured in Europe and is little used in the United States. Double superphosphate contains 35 to 45 per cent. of phosphoric acid in soluble forms.

Thomas Slag is more familiarly known as odorless phosphate. It is also known under several other names, such as basic iron slag, Thomas scoria, phosphate slag, etc. This is a comparatively new source of phosphoric acid compounds. It is a by-product formed in the manufacture of iron and steel from certain kinds of iron ore—containing phosphorus compounds. In the process a phosphate of lime is formed, which is ground to a fine powder. Odorless phosphate is insoluble in water but is somewhat soluble in ammonium citrate solutions and its phosphoric acid is, therefore, available to some extent. The phosphoric acid is in the form known as tetra-calcium phosphate. It contains 15 to 20 per cent. of phosphoric acid, about one-third of which is citrate-soluble, and, in addition, large proportions of lime and iron oxide. The practical results coming from the use of this form of phosphoric acid compounds have been varied, often being most excellent and again very indifferent.

In the table following, we give the amounts of different forms of phosphoric acid found in different phosphate materials:

Table Giving Approximate Amount of Phosphoric Acid in Fertilizing Materials.

Materials containing Phosphoric Acid.	Available Phosphoric Acid.		Insoluble Phosphoric Acid.		Total Phosphoric Acid.	
	Per cent.	Pounds in 2,000 pounds of material.	Per cent.	Pounds in 2,000 pounds of material.	Per cent.	Pounds in 2,000 pounds of material.
Apatite,	....	....	33 to 40	660 to 800	33 to 40	660 to 800
Bone-ash,	....	....	30 to 35	600 to 700	30 to 35	600 to 700
Bone-black,	....	....	25 to 35	500 to 700	25 to 35	500 to 700
Bone-black (dissolved),	12 to 18	240 to 360	1 to 2	20 to 40	13 to 18	260 to 360
Bone-meal,	4 to 8	80 to 160	16 to 17	320 to 340	20 to 25	400 to 500
Bone-meal (from glue factory),	6 to 8	120 to 160	16 to 20	320 to 400	22 to 28	440 to 560
Bone-meal (dissolved),	12 to 18	240 to 360	2 to 8	40 to 160	14 to 20	280 to 400
Caribbean guano,	....	....	....	....	18 to 20	360 to 400
Cuba guano,	....	....	....	....	12 to 14	240 to 280
Double superphosphate,	35 to 45	700 to 800	....	....	35 to 45	700 to 800
Florida rock,	....	....	....	....	25 to 35	500 to 700
Florida soft phosphate,	....	....	....	....	18 to 30	360 to 600
Keystone concentrated phosphate,	35 to 40	700 to 800	7 to 8	140 to 160	45 to 48	900 to 960
Mona Island guano,	7 to 8	140 to 160	13 to 15	260 to 300	20 to 22	400 to 440
Navassa phosphate,	....	....	....	....	28 to 35	460 to 700
Orchilla guano,	....	....	....	....	25 to 30	500 to 600
Peruvian guano,	5 to 8	100 to 160	5 to 7	100 to 140	10 to 15	200 to 300
South Carolina rock (ground),	....	....	....	....	25 to 30	500 to 600
South Carolina rock (floats),	....	....	....	....	25 to 30	500 to 600
South Carolina rock (dissolved)	10 to 12	200 to 240	2 to 4	40 to 80	12 to 16	240 to 320
Thomas Slag (American),	6 to 7	120 to 140	12 to 13	240 to 260	18 to 20	360 to 400

(c) *Fertilizing Materials Containing Potash Compounds.*

The more common sources of potash compounds for use as fertilizers, found in the market, are the following: *Carnallite*, *cotton-seed hull ashes*, *green-sand marl*, *kainit*, *krugite*, *muriate of potash*, *nitrate* *of potash, sulphate of potash, sulphate of potash and magnesia, tobacco stems, wood-ashes, etc.*

Wood-ashes formerly constituted the main source of potash compounds in our agriculture, aside from what was furnished by farm-manures. But for some years past the chief source of potash supply has been the different compounds obtained from the German potash mines at Stassfurt in northern Germany. The deposits are so extensive as to appear inexhaustible.

Carnallite is one of the products of the German potash mines. It contains from 20 to 22 per cent. of muriate of potash, equivalent to 13 to 14 per cent, of actual potash, together with chloride of magnesia and a very small amount of sulphate of potash and magnesia. It is essentially a mixed chloride or muriate of potash and magnesia. The material is generally purified and concentrated before reaching market.

Kainit is the most common product of the German potash mines. It is a mixture of several different compounds, containing 23 to 26 per cent. of sulphate of potash, equivalent to 12 to 14 per cent. of actual potash, together with about 35 per cent. of common salt, some sulphate and chloride of magnesia and a small amount of gypsum.

Krugite is a low-grade potash compound obtained from the German potash mines. It contains from 14 to 16 per cent. of sulphate of potash, equivalent to 8 or 9 per cent. of actual potash, together with considerable gypsum, sulphate of magnesia and some salt.

Muriate of Potash, also a product of the Stassfurt mines, is the main source of supply of potash for commercial fertilizers in our market. As taken from the mine it varies in purity, but is purified and concentrated for market. The muriate of potash most common in the market contains 80 to 85 per cent. of this product, which is equivalent to 50 to 53 per cent. of actual potash. A still more concentrated form, containing 95 to 98 per cent. of pure muriate, is sometimes found in the market.

Sylvinit resembles kainit, containing about 15 to 16 per cent. of actual potash in the form of both sulphate and chloride. It also contains chlorides of sodium and magnesium. It is little used in this country.

Sulphate of Potash is another product of the German mines. Strictly pure sulphate of potash contains about 54 per cent. of actual potash, but the product found in the market is of variable composition and purity. The highest grade of commercial sulphate of potash is 90 to 95 per cent. pure and contains from 48 to 51 per cent. of actual potash. Low-grade sulphates contain as little as 30 per cent. of actual potash, together with more or less sulphate of magnesia and common salt.

Sulphate of Potash and Magnesia is known also as double manure salts or simply as double potash salts. This material comes from the German mines, and contains 48 to 52 per cent. of sulphate of potash, equivalent to 26 to 28 per cent. of actual potash. It also contains 32 to 36 per cent. of sulphate of magnesia.

Nitrate of Potash, commonly called saltpeter or nitre, is a most valuable fertilizing material for potash and nitrogen also. The demand for its use in the manufacture of gunpowder makes it too expensive to use commonly as a fertilizer. It is found in the market as "crude" nitrate of potash, containing about 44 per cent. of actual potash, and also as "double refined" nitrate of potash, containing about 46.5 per cent. of actual potash.

Cottonseed Hull Ashes were produced in the South at the cottonseed-oil factories where the hulls, after being removed from the cottonseed, were used as fuel. Such ashes contain from 15 to 25 per cent. of potash, in addition to from 7 to 10 per cent. of phosphoric acid. They formed a very valuable fertilizer and were much used South in the manufacture of commercial fertilizers. This material is not commonly found now.

Tobacco Stems contain from 6 to 7 per cent. of potash and about two per cent. of nitrogen. They are ground fine and often used in making commercial fertilizers.

Wood-Ashes contain more or less potash, which is present chiefly in the form of carbonate. The amount of potash in commercial wood-ashes varies from below four to seven per cent., the average being under five per cent. Wood-ashes also contain between one and two per cent. of phosphoric acid. The amount of potash in wood-ashes depends upon a variety of conditions, such as the kind and age of wood, the method of burning, and especially the way in which the ashes are stored. Where ashes have been exposed to the weather or leached, they contain much less potash, often only one or two per cent. Ashes from lime-kilns and brick-kilns are generally so mixed with refuse matter as to possess little value for use as fertilizers. Coal-ashes possess little value for the potash contained in them, for it is very small.

Green-Sand Marl of New Jersey contains, on an average, about five per cent. of potash, which is in an insoluble form, and is, therefore, slow in acting is a fertilizer.

Below we present a tabulated summary, showing the amount of potash contained in different commercial fertilizing materials.

Table Giving Approximate Amount of Potash in Fertilizing Materials.

Materials Containing Potash.	Per cent. of actual potash.	Pounds of actual potash in 2,000 pounds of material.
Carnallite,	13 to 14	260 to 280
Cottonseed-hull ashes,	15 to 25	300 to 500
Kainit,	12 to 14	240 to 280
Krugite,	8 to 9	160 to 180
Muriate of potash (80 to 85 per cent.),	50 to 53	1000 to 1060
Nitrate of potash,	43 to 44	860 to 880
Sulphate of potash (low grade),	28 to 30	560 to 600
Sulphate of potash (high grade),	48 to 51	960 to 1020
Sulphate of potash and magnesia,	26 to 28	520 to 560
Sylvinit,	15 to 16	300 to 320
Waste from powder works,	16 to 18	320 to 360
Wood ashes (unleached),	4 to 8	80 to 160
Wood-ashes (leached,	1 to 3	20 to 60

(*d*) *Farm-Produced Fertilizing Materials.*

Economic Value of Farm-Manures.—A fair estimate of the fertilizing value of the manure annually produced by the farm animals of the United States, places the sum at the enormous figure of over two thousand million dollars. This estimate is based on the number of farm animals and on the amount of nitrogen, potash, and phosphoric acid excreted in their manure. The values given to these forms of plant-food are those commonly assigned to them in the form of commercial fertilizers. It will thus be readily seen that the farm-produced manures assume an economic importance which has not been accorded them by the average farmer.

Definition of Stable or Farmyard Manure.—Stable or farmyard manure consists of the solid and liquid excrements of animals fed upon the farm, mixed or unmixed with straw and waste products of the farm.

Variation in Composition of Farm-Manures.—The composition of stable-manure varies greatly, depending on several conditions, among which the following may be mentioned:

(1) The kind and age of the animal producing it.
(2) The quantity and quality of the food eaten.
(3) The character and amount of material used for litter.
(4) The length of time the manure has been kept.
(5) The manner in which it has been cared for.

Influence of Kind of Animal on Manure.—*Horse Manure* is difficult to mix thoroughly with litter on account of its being very dry. It is called a "hot" manure, because, on account of its loose texture, it easily undergoes decomposition or fermentation, producing a high degree of heat. On this account it is very liable to lose more or less of its nitrogen in the form of ammonia. It should have very careful treatment in respect to the litter used and also in the application of preservatives. It is a quick-acting manure. Horses are usually fed with greater uniformity in respect to character of food than other farm animals and there is, therefore, greater uniformity in the composition of horse manure. The urine of horses is particularly rich in nitrogen and potash. It has been estimated that horses excrete somewhat over half their manure in the stable or, on an average, about six tons a year.

Sheep Manure is quite dry and is commonly the richest of farm-produced manures. Like horse manure, it undergoes fermentation easily and is classed as a "hot" or quick-acting manure. It is similarly very liable to lose ammonia.

Pig Manure varies greatly in composition, but is generally rich, though containing considerable water. In decomposing, it produces little heat and is, therefore, called a "cold" manure. It is classed as a slow-acting manure. When pigs are well fed, their liquid excrement is rich in nitrogen.

Cow Manure contains as a rule, less fertilizing materials than any of the preceding manures. It contains a large amount of water, and, in decomposing, generates little heat and is slow-acting. A well-fed cow, producing milk, excretes 20 to 30 pounds of liquid manure and 40 to 50 pounds of solid manure. About one-half of the nitrogen produced is in the urine.

Poultry Manure contains a comparatively large amount of all the different forms of plant-food, being especially rich in nitrogen and potash. It undergoes fermentation readily and loses nitrogen unless properly treated with absorbents or preservatives. It is a very quick-acting form of plant-food. A single hen produces 40 to 60 pounds a year of manure.

Influence of Age of Animal on Manure.—A young, growing animal requires and retains in its body a greater quantity of nitrogen, potash, and phosphoric acid compounds than does a grown animal. Therefore, manure from a young animal is of less value than that from a mature one. Full-grown animals, not varying in weight, excrete essentially all the fertilizing constituents taken into the body in the food. In the case of growing animals and cows in milk, from 50 to 75 per cent. of the fertilizing constituents of the food passes into the manure; in the case of fattening or working animals, from 90 to 95 per cent.

Influence of Food upon Manure.—In the case of any one class of animals, the value of the manure is, as a rule, more dependent upon the kind of food than any other one condition. It is a serious but not uncommon mistake among farmers to suppose that the process of animal digestion *adds something* to the food. While the food materials are changed more or less completely and appear in the dung and urine in forms different from those existing in the food before it was eaten, and while these forms are, in general, more available as plant-food than the forms existing in the original food, still there can be in the excrement no more nitrogen, potash, phosphoric acid. etc., than there was in the food eaten, and, in most cases, as will be noticed later, there is some loss of fertilizing materials.

Relative Value of Fertilizing Materials in Different Classes of Foods.—The amount of nitrogen, phosphoric acid, and potash in manure depends upon the amount of these materials in the food. From the table given below, it can be seen that concentrated foods, such as meat-scrap, cottonseed-meal, linseed meal, and wheat bran must yield richest manures. Next to these foods, would come leguminous plants, such as clover, alfalfa, etc. The cereals, such as wheat, oats, corn, etc., would follow third. Root crops would come last.

Table Showing Approximate Fertilizing Value of Some Common Foods.

Kind of Food.	Value of nitrogen in 2,000 pounds.	Value of phosphoric acid in 2,000 pounds.	Value of potash in 2,000 pounds.	Total fertilizing value in 2,000 pounds.
Meat scrap,	$30 00			$30 00
Cottonseed-meal,	16 00	$2 15	$1 45	19 60
Linseed-meal,	13 80	1 50	1 15	16 45
Gluten-meal,	12 00	25	5	12 30
Wheat bran,	6 60	2 35	1 45	10 40
Clover hay (red),	4 20	40	1 60	6 20
Alfalfa hay,	4 40	45	1 35	6 20
Wheat,	4 70	65	45	5 80
Oats,	4 00	65	50	5 15
Corn-meal,	3 50	55	35	4 40
Timothy hay,	2 50	35	1 25	4 10
Wheat straw,	1 20	10	40	1 70
Skim-milk,	1 40	30	20	1 90
Corn ensilage,	55	10	30	95
Turnips,	40	10	30	80

It will be readily seen that of two foods costing the same price and having equal feeding value, it is economy for the farmer to use that one which contains the largest amount of fertilizing materials.

Amount of Fertilizing Materials of Food Recovered in Manure.—Generally speaking, manure produced from working or fattening animals contains from 90 to 95 per cent. of the fertilizing constituents contained in the food. Manure made from cows in milk and young, growing animals contains from 50 to 75 per cent. of the fertilizing constituents contained in the food. In the case of animals which are neither increasing in weight nor giving milk, the amount of fertilizing materials in the manure will be exactly equal to that contained in the food eaten. The foregoing statements pre-suppose that all the dung and urine are saved, a supposition which is not often true, considering the manner in which stable-manure is commonly treated.

The Digestibility of Food and Its Manurial Value.—The solid excrements of animals consist largely of the undigested portions of food; these undigested portions are mostly insoluble and, therefore, not immediately available as plant-food. The urine contains those portions of food which have been digested; its constituents are all in a soluble form and readily available as plant-food, and, therefore, more valuable than the insoluble fertilizing materials contained in the solid excrement. It therefore follows that the more digestible a food is, the larger is the proportion of its fertilizing constituents that will appear in the urine, and the greater will be the value of the plant-food in the manure produced.

The Use of Litter.—Litter is used in stables primarily to furnish a clean and comfortable bed for animals. In connection with the manure, it is used to absorb the liquid portion of the manure, thus preventing loss by drainage. The presence of litter mixed with manure makes the manure easier to handle, tends to check and control its decomposition, and in some cases influences both the physical and chemical action of the manure. The materials commonly used for litter are usually not rich in fertilizing materials. The use of too much litter diminishes the relative value of the manure and adds to the cost of handling. Enough should be used not only to absorb and retain the urine, but also to absorb any ammonia formed in the process of decomposition.

Fermentation of Manure.—*Causes.*—It is a familiar experience of every farmer that fresh stable-manure, when left in a heap, commences very soon to ferment or undergo decomposition. In this process the vegetable matter used as litter and the excrements pass through several changes. The fermentation is caused by minute living organisms, and varies according to the kind of organisms at work. Some will flourish only in the presence of an abundant supply of air, others will thrive only away from air; some require much moisture, others little, etc. According to circumstances, then, one kind or another will flourish, and the fermentation taking place will vary according as it is caused by the action of one kind of organism or another.

Conditions.—The more important conditions influencing the character of fermentation in manure are the following: (1) Temperature, (2) moisture, (3) the amount of air supplied as regulated by looseness or compactness of manure heap, (4) the composition of the manure, and (5) the kind of preservatives added.

Manure ferments more quickly at higher temperatures. Where air is supplied freely, as on the outside of the heap, the temperature may rise as high as 150 degrees Fahrenheit or even higher. The most faverable temperature seems to be about 130 degrees Fahrenheit. On the inside of the heap, where the supply of air is very limited, a slower form of fermentation occurs and the temperature rarely goes above 95 degrees Fahrenheit.

If a manure heap is too loose, the fermentation is too rapid. The result is that the humus forming material is destroyed and large proportions of nitrogen escape as ammonia. If, however, the manure is too compact, the fermentation may be so slow as not to decompose the manure enough for its most effective use in the soil.

The amount of moisture in manure is an important factor in controlling the rapidity of fermentation. The addition of water causes reduction of temperature and a corresponding slowless of fermentation. Water, when added in sufficient quantities, also fills up the pores of the heap and serves to exclude air, thus retarding the most active form of fermentation.

Manures which are rich in soluble nitrogen decompose more readily than others which contain less soluble nitrogen. Thus urine decomposes much more rapidly than solid excrement.

Changes Produced by Fermentation.—The principal changes that take place in the more common methods of fermentation or "rotting" of manure may be briefly outlined as follows: (1) The carbon of the manure combines, to a greater or less extent, with the oxygen of the air, forming carbon dioxide (carbonic acid gas), which escapes into the air. (2) The nitrogen combines with hydrogen to form ammonia. If the manure heap is dry, the ammonia combines with carbon dioxide, forming ammonium carbonate, which may escape into the air and be lost to the manure. If the heap is kept moist, certain organic acids are formed by the decomposition of the organic matter, and the ammonia, as fast as it is formed, unites with these acids, producing ammonia salts which readily dissolve in water but which do not escape as gases into the air. (3) Considerable water is driven off from the manure by the heat which is produced in the process of fermentation. (4) In the inner part of the heap, which is shut off from the air, there is serious danger that nitrate-destroying germs will decompose the nitrates and thus cause their loss.

Difference between Fresh and Fermented Stable Manure.—From the foregoing it would follow that fresh stable-manure differs from fermented or "rotted" stable-manure in the following respects: The fresh manure contains (1) more water, and (2) more carbon than the fermented manure; while (3) both contain in their dry matter the same amount of potash, phosphoric acid and nitrogen, provided the process has been carefully managed. In "rotted" manure, (4) the nitrogen is in a more available form as plant-food; the same is also true of the potash and phosphoric acid. (5) If the process of rotting is allowed to go too far the nitrates will be changed into free nitrogen and lost.

Between two and three tons of fresh mixed stable-manure are required to produce one ton of half-rotted manure. The difference in weight is due mainly to water and carbon.

Manure that is very completely rotted so as to form a black, uniform, slimy mass has usually lost most of its nitrate-nitrogen. Half-rotted manure is the form in which stable-manure is quite commonly used. It contains nitrate-nitrogen and is in its most available form.

Loss of Fertilizing Materials in Stable-Manure.—There are two principal ways in which stable-manure commonly loses some of its fertilizing constituents: First, by improper methods of fermentation, and second, by leaching. In regard to the first point, more or less nitrogen is lost by allowing manure to ferment without sufficient moisture; especially is this apt to be true in the case of the manure of horses, hens and sheep, which decomposes very rapidly. A strong odor coming from a manure heap indicates that a wasteful fermentation is taking place. Of plant-food materials, only nitrogen compounds can be lost by vaporization. By leaching there will be a loss, not only of nitrogen compounds, but of potash and phosphoric acid also. The common method of storing farmyard-manure for several months under the eaves of the barn generally results in a loss of one-third or more of the fertilizing constituents by leaching; and, moreover, the materials thus leached out by rain are the more easily soluble portions of the manure and hence the more valuable portions.

Care and Preservation of Farm-Manures.—In caring for farm manures, the main object is to prevent the loss of compounds containing nitrogen, potash and phosphoric acid. From what has been said above in connection with the sources of loss of fertilizing materials in farm-manures, it can be seen that the causes of loss can be avoided by absorbing the liquid manure, by regulating the process of fermentation and by protecting the manure from leaching. We will consider briefly some of the ways in which these objects can be accomplished.

The use of litter absorbs the liquid manure, preserves it to some extent from immediate decomposition, and also holds more or less of the ammonia produced by fermentation, thus preventing its escape into the air. Of the materials in common use, *peat* has the largest power of absorbing and holding liquids; peat-moss comes next; spent tan and saw-dust follow; then come straw and similar materials. It has been given as a safe rule to follow that the litter should at least be equal to one-third of the dry matter of the food consumed. The following daily amounts for different animals have been suggested: Sheep, three-fifths of a pound of litter; cattle, 9 pounds; horses, 6½ pounds. In addition to using litter, it is wise to use some other materials for absorbing and preserving the manure. Among such materials are gypsum (land-plaster), kainit, acid phosphate, etc.

Gypsum (land-plaster) has the power of holding ammonia and preventing its loss. It must, however, be moist in order to be effective. The best way to use gypsum is to sprinkle it on the moist dung or urine. Stables in which the excrements are properly treated by this means are noticeable free from offensive odors, as a rule.

Kainit sprinkled upon manure tends to check fermentation and also to attract and hold moisture. One precaution should be observed in the use of kainit; it should be kept from under the feet of animals, since injury may result to the feet of animals treading on it. It is, therefore, best applied to fresh manure and covered with litter.

Acid Phosphate contains a considerable proportion of gypsum and, to this extent, its action is like that of gypsum. The soluble phosphate in the acid phosphate tends to unite with ammonia and prevent its loss and also to check fermentation.

A mixture of acid phosphate and gypsum is strongly recommended by some, using them in about equal proportions.

For average animals, the following amounts of different preservatives may be used daily for each individual:

Kind of Preservative.	For one horse—pounds.	For one cow—pounds.	For one pig—ounces.	For one sheep—ounces.
Gypsum (land-plaster)	1½	1¾	4½	3½
Acid phosphate,	1	1⅛	3	2½
Kainit,	1⅛	1¼	4	3¼

When a mixture of superphosphate and gypsum is used, take one-half or one-third of the amounts indicated above. One great advantage in using acid phosphate or kainit is that one is adding to the manure an important form of plant-food, in which the manure is naturally deficient. The price at which one can get these materials must determine whether their use is economical or not.

Mixture of different manures, such as cow and horse manures, is advantageous, since one undergoes fermentation slowly and the other rapidly. When mixed, the conditions of moisture are more easily controlled.

Whether stable-manure is stored in sheds, or in cellars or is protected in some other way, it is important to observe the following precautions: (1) The manure should be spread out uniformly; (2) its interior should be protected against the access of air; (3) it should be kept always moist, but not too wet; (4) it should be protected from sunshine; (5) it should be protected from leaching; (6) some form of preservative should be used in the stables in addition to litter.

Liquid and Solid Manure.—It is not an uncommon belief among farmers that urine is worthless for fertilizing purposes, if we may judge anything from the too general practice of allowing the liquid excrements to run to waste through the barn floor. One has only to glance at the composition of the solid and liquid excrements of different animals as given below to see that the liquid is, in most cases, very much more valuable than the solid portions. Not only are the proportions of nitrogen and potash greater, as a rule, in the liquid excrement than in the solid, but, as already noticed, the fertilizing constituents of urine are entirely soluble and therefore more readily available for plant-food than the constituents of solid excrements.

Table Showing Approximate Composition of Solid and Liquid Manures.

	Pounds of Nitrogen in 100 Pounds.		Pounds of Phosphoric Acid in 100 Pounds.		Pounds of Potash in 100 Pounds.	
	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.
Cows,	0.30	1.30	0.28	0	0.20	1.00
Horses,	0.60	1.55	0.30	0	0.50	1.50
Sheep,	0.80	1.95	0.25	0	0.65	2.25

Table Showing Approximate Composition of Mixed Stable Manure.

	Per cent. of nitrogen.	Pounds of nitrogen in one ton.	Per cent. of phosphoric acid.	Pounds of phosphoric acid in one ton.	Per cent. of potash.	Pounds of potash in one ton.
Least,	0.4	8	0.2	4	0.4	8
Greatest,	0.75	15	0.4	8	0.75	15
Average,	0.50	10	0.25	5	0.50	10

PART III.

THE PURCHASE AND USE OF FERTILIZERS.

One of the questions most commonly asked by farmers seeking information is, "What fertilizer will give me the best results for this or that crop?" It is, of course, impossible to give any definite answer to such a general question involving, as it does so many different conditions, none of which is clearly known. The composition and physical properties of the soil, the extent and manner in which it has been previously cropped and fertilized, the kind of crop one wishes to grow, all these conditions need to be known and, even then, it will require some special experimenting on the part of the farmer to determine what forms and amounts of fertilizers he can use most economically. The common method employed by farmers in selecting fertilizers is to take some brand of complete fertilizer that has been recommended to him by some neighbor or dealer. He has no clear ideas regarding the condition of his soil, and the needs of different crops. He thinks that he must have more fertilizer in order to secure better crops and he buys blindly. Under such circumstances, it is safest, as a rule, for a farmer to select a complete fertilizer. However, in so doing, he may be throwing money away by purchasing what his soil and crop may not need, for only one or two of the three chief fertilizing constituents (nitrogen, potash and phosphoric acid) may be needed; and, indeed, it may be that some physical condition of the soil is wrong and that plant-food of any kind is not really needed at all.

In selecting fertilizers for use, we need to consider several important questions, such as the following:

1. Under what circumstances a fertilizer should be used.
2. What constituents of plant-food are needed.
3. What amount of each fertilizing constituent is needed.
4. In what forms it is best to buy such plant-food as is needed.
5. Which is more advantageous, to purchase complete fertilizers or to purchase separate ingredients?
6. To what extent home-mixing is practicable.
7. Special suggestions in connection with the purchase of separate ingredients.
8. Methods and seasons of applying fertilizers.
9. The most advantageous methods of using farm-produced manures.
10. The use of green manures.
11. Rotation of crops.
12. The use of lime on soils.
13. Plant-food mixtures for different crops.

1. Under What Circumstances Should a Commercial Fertilizer be Used?

One must resort to the use of commercial fertilizers when he has exhausted all of the resources of the farm in producing his own fertilizing materials and finds that the use of commercial fertilizers will result in increased crops and profit. When the farmers' crops can not get from the soil as much nitrogen, potash and phosphoric acid as they need, and when the manure made on the farm can not supply the constituents in sufficient quantity, then one may resort successfully to the use of commercial fertilizers. One must secure an increase of crop sufficient to pay for the fertilizer used and for the cost of labor in applying it and have something in addition in order to make the use of commercial fertilizer a paying operation.

However, one must distinguish between lack of plant-food in the soil and other conditions which prevent good crops, for lack of food is not the only cause that makes crops suffer. In some soils there is, for example, a tendency to harden, causing lack of porosity, which prevents the development of roots and thus limits the feeding power of the plant. Such condition may be overcome by adding humus to the soil together with proper tillage. Other unfavorable conditions may be lack of moisture, retention of stagnant water, deficiency of lime, acidity of soil, climatic influences, etc., which may interfere with the healthy growth of plants and thus cause diminished crops, even when the plant has within reach all the food it needs. Under such circumstances, the unfavorable conditions must, if possible, be removed to secure good crops; and this, according to the demands of special cases, may be done by irrigating, draining, deep culture, better ploughing, harrowing, hoeing, marling, liming, mucking, etc.

It often happens that a soil contains an abundance of plant-food, most of which is in unavailable forms. Under such circumstances an effort should be made to bring this food into an available condition as rapidly as plants can use it. Briefly stated, this can be done to some extent by the use of indirect fertilizers, like gypsum, lime, and salt, by the use of organic manures, by growing deep-rooting crops, by judicious use of drains, and by vigorous and thorough tillage.

It cannot be too strongly emphasized that, before one can advantageously approach the question of the economic use of commercial fertilizers, he must make sure that all those conditions of soil are present which are essential to the favorable growth of crops, in addition to plant-food supply.

It will thus be seen that it is not always so simple a matter to tell when one should use commercial fertilizers. But the general rule will be to use them when their use is attended with increased profit coming from increased crops, and this can be learned with certainty only by actual trial. Attention will be called later to specific methods for making field tests.

2. What Constituents of Plant-Food are Needed.

When it has been clearly settled that a soil needs the addition of plant-food in order to grow crops more successfully, the question at once presents itself as to what kinds of plant-food are required. Does some form of nitrogen need to be supplied, or is it phosphoric acid that is needed, or is it potash? It may be only one, it may be some two, or it may be all three of these constituents are necessary to grow crops to the best advantage. *How can we ascertain what kind of plant-food is required?*

Analysis of Soils.—It was formerly thought that an analysis of the soil would answer this question beyond doubt. But it is now known not to be especially helpful except, perhaps, in a negative way by making known the fact when there is little or no plant-food in the soil. A chemical analysis may show an abundance of plant-food in the soil, and yet this may be mostly unavailable, a fact which is not readily ascertained by our methods of chemical analysis. Again, there may be an abundance of nitrogen, potash and phosphoric acid compounds in the soil in an available condition, and yet the soil may be unproductive from lack of humus, from need of proper drainage, from lack of porosity, or from some other cause which affects the mechanical or physical condition of the soil in such a way as to unfit it for plant growth. Again, we may put upon an acre of soil an amount of fertilizing constituents that will greatly increase the crop, and yet an analysis of the soil before and after the application will show no appreciable difference in the quantity of plant-food present in the acre of soil. However delicate may be the methods of chemical analysis, the methods of plants are still more delicate and plants are able to show differences in soil where chemical analysis distinguishes none.

Indications of Needs of Soil Afforded by Appearance of Crops.—It is impossible to give any fixed rules which will cover all cases and enable a farmer to tell without any experiment on his part what food constituents his soil lacks. In a general way, the crops themselves may give some valuable suggestions.

(*a*) As a rule, *lack of nitrogen* is indicated, when plants are pale-green in color, or when there is a small growth of leaf or stalk, other conditions being favorable.

(*b*) A bright, deep green color, with a vigorous growth of leaf or stalk, is, in case of most crops, a sign that *nitrogen is not lacking* but does not necessarily indicate that more nitrogen could not be used to advantage.

(*c*) An excessive growth of leaf or stalk, accompanied by an imperfect bud, flower, and fruit development, indicates *too much nitrogen* for the potash and phosphoric acid present.

(*d*) When such crops as corn, cabbage, grass, potatoes, etc., have a luxuriant, healthful growth, *an abundance of potash* in the soil is indicated; also, when fleshy fruits of fine flavor and texture can be successfully grown.

(*e*) When a soil produces good, early maturing crops of grain, with plump and heavy kernels, *phosphoric acid will not generally be found deficient* in the soil.

Such general indications may often be most helpful, and the condition of crops should be studied carefully with these facts in mind.

Plant-Food Needs in Relation to Kind of Soil.—The kind of soil may furnish information as to what kind of plant-food is apt to be lacking. While soils of the same class differ widely in composition, there are certain general suggestions which they may afford. In *sandy* soils potash is commonly deficient and hence this element must be a prominent ingredient of a fertilizer for such a soil. Sandy and gravelly soils usually require liberal amounts of phosphoric acid also, owing to the fact that in such soils phosphate compounds are liable to leach beyond reach of plants. On the other hand, *clay* soils are usually well supplied with potash and are apt to be deficient in phosphoric acid and lime. In *lime* soils there may be a lack of nitrogen.

Plant-Food Needs of Soils in Relation to Previous Crops.—The growing of the same kind of crop continuously on the same land is exhausting in regard to one or more elements of plant-food. Thus, wheat grown year after year on the same soil exhausts nitrogen and phosphoric acid more rapidly than potash; hence, phosphoric acid and nitrogen without potash would in most such cases give fully as good results as with potash, at least for a time. The continuous growth of grass crops takes large amounts of potash compared with phosphoric acid. Where there has been such a system of farming employed, one element will usually be found to have been removed more extensively than others, and in feeding crops, this lacking element is the one that especially needs to be supplied.

It often happens that in a system of rotation all elements of plant-food are removed in about the same proportion, and hence restoration of high productiveness means addition of nitrogen, phosphoric acid and potash.

Plant-Food Needs of Soils in Relation to Specific Classes of Plants.—The food needs of different classes of plants vary in a marked degree and their general requirements should be studied if we try to feed them intelligently. For the purpose of calling attention to the main facts, we can divide most of our common crops into the following classes:

Root and tuber crops, grasses, leguminous crops, cereals, fruit crops, market-garden crops.

(*a*) *Root and Tuber Crops* include such crops as turnips, beets, mangels, carrots, potatoes, sweet potatoes, etc. While these crops need all elements of plant-food, turnips appear to make especially good use of available phosphoric acid in their early stages of growth. Beets and carrots grow less quickly and need nitrogen in readily available forms. Potatoes need liberal supplies of available potash. These crops, owing to their habits of growth, do not make quick use of the insoluble mineral plant-food of the soil, especially in their early stage of growth.

(*b*) *Grasses* are mostly perennial, though their length of life depends upon a variety of conditions, such as methods of cropping, kind of soil, etc. They are mostly surface feeders in their early stages of growth. They have the power of using potash and phosphoric acid in its less soluble forms quite easily. It is of advantage, however, to supply them with easily available forms of nitrogen which should be fed them quite liberally, because the object of the crop is leaf and stem for pasture or hay or forage, and nitrogen promotes this form of growth.

(*c*) *Leguminous Crops* such as clover, peas, beans, vetches, etc., have the power of securing nitrogen from the air, but need very liberal supplies of potash and phosphoric acid.

(*d*) *Cereals* possess certain marked characteristics in their methods of growth and feeding. Their roots branch just beneath the surface and each separate shoot sends out feeding roots in every direction, thus reaching the lower layers of the soil in the later stages of growth. Their peculiar root system enables cereals to feed quite readily upon the less soluble potash and phosphoric acid compounds of the soil. A considerable part of the growth of many of these crops occurs early in the season before the unavailable nitrogen is changed into nitrates and, therefore, they are, with the exception of Indian corn, greatly helped by early applications of nitrate-nitrogen. Hence, early application of nitrate nitrogen helps wheat, rye, oats and barley. With corn, the growth comes largely after other cereals have ripened, in July and August, and by this time the insoluble soil nitrogen has changed largely into nitrates.

(*e*) *Fruit Crops.*—Fruit trees are slow in growth and slow feeding; hence they can utilize less available forms of plant-food. Their supplies of food should be of such a character as to favor slow and continuous rather than rapid growth. For example, ground bone is a good source of nitrogen and phosphoric acid.

(*f*) *Market-Garden Crops* include many crops greatly varying in their feeding habits, but they are all raised with one object in view—to secure tenderness and succulence by means of very rapid growth.

This is secured by large applications of nitrate-nitrogen along with very liberal quantities of potash and phosphoric acid.

In order to ascertain with greater certainty what food elements are lacking in the soil, the surest way is for each farmer to do some experimenting on his own soil and crops. The exact manner of doing this will be considered under the following head in connection with the amount of plant-food to be used.

3. What Amount of Each Fertilizing Constituent is Needed.

Inseparably connected with the question of what elements of plant-food are needed is the question, "How much of each element is needed?" Perhaps, the question more often asked than any other relates to the quantities in which fertilizers should be applied. Granting that we know fairly well whether we need to use nitrogen, or phosphoric acid or potash compounds, or some combination of these, how can we ascertain how much to put on an acre of land? This question is quite as complicated as the preceding one. A variety of conditions must be considered. If we knew how much available plant-food there were in an acre of soil, and how much the growing crop would require, the matter would be comparatively simple, provided the mechanical condition of the soil was satisfactory. The form of fertilizing material used would also need consideration.

There are two extremes which we must strive to avoid. On the one hand, we can assume that the supply of food in the soil is fairly abundant and make only small additions, thus running the risk of using too small amounts for growing a good crop. On the other hand, we may assume that the supply of food in the soil is decidedly deficient and put on quantities of fertilizing material sufficient in itself to grow a good crop. In this case, we run the risk of putting on more than the present crop needs. If we can not hit upon the desired medium, putting on amounts that will grow the best crop most economically without leaving too much plant-food over, it is better to make the mistake of putting on too much than too little. Only individual experimenting can determine in each case how much nitrogen, potash, and phosphoric acid can be used to best advantage, and to this line of work attention will now be given.

Experiments in Learning Plant-Food Needed.—In order to ascertain with certainty what food elements are lacking in the soil, the surest way is for each farmer to do some experimenting on his own soil and crops. In fact, if farmers are unwilling to carry out some simple experiments for themselves on their own farms and with their own crops, they cannot expect ever to make use of plant-food in the most economical and intelligent manner.

It is our purpose now to indicate in some detail how such experimenting can be done by individual farmers.

(*a*) *Selection of Land for Field Tests.*—The land selected for testing plant-food needs should be in good condition in respect to tillage, drainage, etc. The soil should be as much alike as possible throughout the test field. It is desirable also that the surface shall be quite level and uniform. The more worn-out the soil is, the more definite results may be expected.

(*b*) *Size of Experimental Plots.*—A convenient size of plot to use for a field test is one-twentieth of an acre, containing an area of 2,176 square feet. The length and breadth of the plots can be such as suits one's convenience, but it is recommended that each plot measure 204 feet in length by ten feet eight inches in width. Between the plots, leave a strip unused three or four feet wide so as to avoid any possible mixing of the different plots.

(*c*) *Preparation of Land.*—Select a portion of the field that represents a fair average, and that has been cropped and manured alike previously; prepare the soil as carefully as possible for the crop and then *measure accurately* and stake out into plots 204 feet long, and ten feet eight inches wide, leaving between the plots a strip three or four feet wide. Mark each plot by a number corresponding to the kind of fertilizer used, following a diagram previously laid out on paper.

(*d*) *Application of Fertilizer.*—Distribute each fertilizer over its own plot, mixing it thoroughly with the soil and keeping the fertilizer from going outside the plot. It is better to apply the fertilizer broadcast and before planting, if the crop is not a cultivable one. For cultivable crops the fertilizer may be applied after planting and harrowed in. On the basis of the amounts of fertilizer given below, there will be one pound of fertilizer or an even multiple of it for each square rod of surface.

(*e*) *System in Conducting Fertilizer Experiments.*—The work must be done from beginning to end systematically and accurately, if best results are to be obtained. The harvested crop must be carefully measured and a record kept of all results.

(*f*) *Plan of Experiment.*—The following diagram represents an arrangement of plots, together with the kinds and amounts of plant-food materials to use. The particular crop with which to experiment may be left to the choice of the farmer. For first trials corn, or potatoes, or oats may be used, to be followed by such others as are usually raised by the farmer. The work should be carried on for more than one season. It must be kept in mind that weather conditions may seriously interfere to destroy the value of the results. An excessively dry season works against satisfactory results. Therefore the work should be repeated. All the plots should receive the same amount and kind of cultivation. The same amount of seed should be used. In a word, keep all conditions of treatment as much alike as possible, except for the application of fertilizers.

Plot No. 1,	Blank,	No fertilizer.
Plot No. 2,	Eight pounds,	Nitrate of soda.
Plot No. 3,	Sixteen pounds,	Dissolved rock.
Plot No. 4,	Eight pounds,	Muriate of potash.
Plot No. 5,	Eighty pounds,	Air-slaked lime.
Plot No. 6,	Eight pounds, Sixteen pounds,	Nitrate of soda. Dissolved rock.
Plot No. 7,	Eight pounds, Eight pounds,	Nitrate of soda. Muriate of potash.
Plot No. 8,	Sixteen pounds, Eight pounds,	Dissolved rock. Muriate of potash.
Plot No. 9,	Eight pounds, Sixteen pounds, Eight pounds,	Nitrate of soda. Dissolved rock. Muriate of potash.
Plot No. 10,	Blank,	No fertilizer.
Plot No. 11,	Two hundred and fifty pounds.	Stable manure, well-rotted.
Plot No. 12,	Two hundred and fifty pounds.	Air-slaked lime.

It may be desirable the first year to limit the work to the first five plots, and then extend it as experience is acquired.

(*g*) *Interpretation of Results.*—If Plots No. 1 and No. 10 give as good results in crops as any other, then the soil is in good condition as regards its present plant-food supply. If Plot No. 2 gives increased yields, the need of nitrogen is indicated. An increase of crops on Plot No. 3 indicates need of available phosphoric acid, and increase on Plot No. 4 shows need of potash. Increase of crops on Plots No. 5 and No. 12 shows probable acidity of soil or presence of unavailable potash compounds in soil or else lack of lime sufficient for plant-food. If Plot No. 11 gives better results than other plots, there is probably a lack of humus in the soil. If Plot No. 6 shows no increase of crop, then nitrogen and phosphoric acid are not deficient in soil. The other plots are to be interpreted similarly in accordance with the behavior of crops.

The amounts of plant-food materials indicated above are larger than will be used on many soils and crops. But when once it is found that any particular element of plant-food increases a crop, then some additional trials can be made to ascertain the smallest amount of application that will give most economical results. The factors that determine the amount of plant-food needed are: (1) the amount of available plant-food present in the soil, (2) the amount of plant-food required by the crop grown, and (3) the kind of farming carried on.

How Can We Determine the Amount of Available Plant-Food Present in the Soil?—The method given above is essentially the only practicable and reliable means we have at present for ascertaining whether or not there is in a soil enough available plant-food of any particular kind to grow a crop satisfactorily. As already pointed out this information cannot be gained with certainty by a chemical analysis of soil. Farmers cannot be too strongly impressed with the necessity of carrying out some such experiments as those indicated above. Such experiments can be carried on with very little extra work. This line of work, properly conducted, will not only furnish the farmer information that is of the greatest practical and economical value to him, but it will exert a marked educational influence upon him, making him personally familiar with plant-food materials, causing him to take a deeper interest in the growing of crops, and leading him to practise better methods.

Amount of Plant-Food Required by the Kind of Crop Grown.—It is a well-known fact that different crops need different quantities of nitrogen, potash and phosphoric acid compounds. If we know with a fair degree of accuracy how many pounds of nitrogen, potash and phosphoric acid a crop of any kind will remove from the soil, then we have fairly definite knowledge of the amounts of different forms of plant-food to apply to the soil to insure a crop. If we could not depend upon the soil to furnish any plant-food, then we should use, at least, the amounts of fertilizing materials removed by one crop.

In the following table, we give the number of pounds of nitrogen, phosphoric acid and potash used by different kinds of crops grown on one acre of land. The yields have been made variable within fairly wide limits so as to cover most cases found in actual experience. The calculations are based upon the most reliable analyses available.

In studying this table, we must keep in mind that the figures do not in every case represent the amount of plant-food removed from the soil. Thus, with clovers, beans, peas and other leguminous crops, a portion of the nitrogen is obtained from the air and hence we need to apply less nitrogen in the form of fertilizer than appears to be called for by the table. In the case of fruits, like apples, pears, plums, etc., it will be found safe often to apply larger quantities than the table calls for, because the figures in the table do not indicate the demands made by the tree in increasing growth:

Approximate Amount of Fertilizing Materials Contained in One Crop Grown on One Acre.

Kind of Crop.	Yield of Grain, Fruit, Etc.	Yield of Straw, Etc.	Pounds of nitrogen.	Pounds of phosphoric acid.	Pounds of potash.
Apples,	10 to 20 tons.	—	26 to 52	2 to 4	40 to 80
Barley,	20 to 40 bu.	1,350 to 2,700 lbs.	35 to 70	11.5 to 23	34 to 68
Beans,	20 to 40 bu.	1,800 to 3,600 lbs.	75 to 150	20 to 40	55 to 110
Buckwheat,	15 to 30 bu.	1,200 to 2,400 lbs.	20 to 40	10.5 to 21	17.5 to 35
Cabbage,	15 to 30 tons.	—	100 to 200	35 to 70	135 to 270
Clover, crimson (green),	—	7½ to 15 tons.	65 to 130	20 to 40	70 to 140
Clover, red (hay),		1 to 2 tons.	41 to 82	10 to 20	40 to 80
Corn.	30 to 60 bu.	2,500 to 5,000 lbs.	42 to 84	16 to 32	17 to 34
Grapes,	1 to 2 tons.	3,000 to 6,000 lbs.	7 to 14	18 to 36	26 to 52
Hops (whole crop),	1,600 to 3,200 lbs.	—	40 to 80	28 to 56	32 to 64
Mixed hay,	—	1 to 2½ tons.	28 to 70	7 to 17.5	31 to 77
Oats.	30 to 60 bu.	1,600 to 3,200 lbs.	30 to 60	11 to 22	25 to 50
Onions,	350 to 700 bu.	—	35 to 70	10 to 20	30 to 60
Pears,	8 to 16 tons.	—	16 to 22	5 to 10	13 to 26
Peas,	15 to 30 bu.	1,500 to 3,000 lbs.	50 to 100	16.5 to 33	26 to 52
Plums,	4 to 8 tons.	—	15 to 30	2 to 4	20 to 40
Potatoes,	100 to 200 bu.	750 to 1,500 lbs.	25 to 50	10 to 20	35 to 70
Rye.	15 to 30 bu.	2,100 to 4,200 lbs.	24.5 to 49	13 to 26	21 to 42
Sugar beets,	300 to 600 bu.	3,000 to 6,000 lbs.	55 to 110	20 to 40	95 to 190
Timothy hay,	—	1 to 2 tons.	25 to 50	10 to 20	30 to 60
Tobacco,	800 to 1,600 lbs. leaves.	700 to 1,400 lbs. stems.	38 to 76	8 to 16	100 to 200
Tomatoes,	5 to 10 tons.	2 to 4 tons vines.	50 to 100	10 to 20	50 to 100
Turnips,	350 to 700 bu.	2½ to 5 tons.	50 to 100	26 to 52	90 to 180
Wheat,	15 to 30 bu.	1,600 to 3,200 lbs.	31 to 62	10 to 20	13 to 26

An examination of the foregoing table justifies the assertion, when we consider all the conditions, that the smallest amounts of plant-food we can expect to use on an acre of land with any satisfactory results are the following:

Ten pounds of nitrogen.
Fifteen pounds of available phosphoric acid.
Twenty pounds of potash.

To state this in another form, the foregoing amounts of nitrogen would be contained in 200 pounds of a fertilizer having the following composition:

Nitrogen, five per cent.
Available phosphoric acid, seven and one-half per cent.
Potash, ten per cent.

This would be regarded as a high-grade fertilizer, and on some soils an application of 200 pounds an acre would be considered large, while on others it would be entirely insufficient. The above rule will probably be found fairly safe to follow in fertilizing average crops, when we know nothing at all in regard to soil or crops.

Kind of Farming.—The amount of plant-food required for the economical growth of plants must depend to some extent upon the specific character and method of farming. In the case of garden truck crops, where it is desired to secure maximum crops at the earliest possible time of season, it is the practice to apply amounts of plant-food which would be considered excessive in general farm practice. The farmer who practices an intelligent form of rotation can raise crops with less expenditure for fertilizers than can the one who does not use a desirable form of rotation. The subject of rotation of crops is of such importance in connection with the use of plant-food, that we will later consider it in some of its more important applications.

4. In What Forms is it Best to Buy Plant-Food.

We have previously seen that we can obtain nitrogen in several different forms, such as nitrate of soda, sulphate of ammonia, dried blood, tankage, fish-scrap, etc. Similarly we find in the market phosphoric acid obtained from several different sources, and we also find several different potash compounds. When we come to use fertilizing materials as a source of plant-food, we must decide which specific forms we shall apply. To illustrate, in applying some form of nitrogen, shall we use nitrate of soda, or sulphate of ammonia, or dried blood, or fish-scrap? Shall we use as our source of phosphoric acid bone-meal, dissolved bone, acid phosphate, dissolved bone-black or Thomas slag? Shall we apply muriate of potash, or sulphate of potash, or carbonate of potash? What principles are there to guide us in making the best choice?

In deciding what form of material to use for plant-food, we should be guided by

(1) The availability of the plant-food,
(2) The preference, if any, shown by different plants, and
(3) The comparative economy possible in purchasing different materials.

Availability of Different Forms of Plant-Food.—As a rule, commercial fertilizers are used for the purpose of increasing the single season's crop to which they are applied. Most farmers plan to give to each succeeding crop by itself the plant-food it needs, and to avoid supplying any one crop with more material than it can use to best advantage. This is especially true of those who do not own the farms which they work and who plan each year's work by itself without reference to the future. Under such circumstances a farmer desires to use those forms of fertilizing materials which will be taken up most quickly and completely by the crops. On the other hand, the farmer who owns his land frequently desires to use materials, the plant-food of which will be utilized gradually by crops and which will last through several seasons. It will thus be seen that if one desires a fertilizer which will act at once and be largely used up by the present crop, then he will need to purchase his plant-food in forms different from those purchased by the man who desires more lasting benefits, extending through several seasons.

We will now consider the relative rapidity with which different forms of nitrogen, phosphoric acid, and potash are available for the use of plants.

(*a*). *Availability of Different Forms of Nitrogen.*

(*1*) *Nitrate of Soda* is easily soluble in water and is utilized as such directly by plants. Therefore, as soon as nitrate of soda dissolves and reaches the root system of plants, it is immediately absorbed and used as plant-food. The ease with which it dissolves in water enables it, in the presence of moisture, to distribute itself quickly through the soil and reach the plant roots. Hence, on account of its ease of solution and immediate absorption and utilization by plants, nitrate of soda is the most available form of nitrogen that we can use in feeding plants. Under favorable conditions the effect of applying nitrate of soda to plants may be seen in one or two days.

(*2*) *Ammonia Compounds* follow nitrate of soda in point of availability as plant-food. The most common ammonia compound used is sulphate of ammonia. It is easily soluble in water and has like nitrate of soda, the advantage of quick distribution in the soil within reach of the plant roots. However, unlike nitrate of soda, it is a form which plants do not absorb and use as such to any marked extent, if at all. Therefore, sulphate of ammonia or any ammonia compound must first be changed in the soil into the form of nitrate compounds before plants can utilize it as food. This change takes place quite rapidly under favorable conditions. Sulphate of ammonia gives better results than nitrate of soda in very wet seasons, because the latter may be washed down into the soil beyond reach of the roots. Another advantage is that the action of nitrogen in the form of sulphate of ammonia is more gradual and prolonged, when such action is desired rather than very quick action.

(*3*) *Dried Blood* is one of the most quick-acting organic materials used for fertilizers, but is less rapid than sulphate of ammonia or nitrate of soda. Its organic nitrogen passes through a series of changes by which it is transformed into ammonia and finally into nitrate compounds, before being used by plants.

(*4*) *Fish*, dried and ground fine, is a little slower in its action than dried blood in furnishing nitrogen.

(*5*) *Tankage* is still slower in action than the preceding forms of animal matter. Its rapidity of action increases with its fineness.

(*6*) *Bone* furnishes nitrogen with varying degrees of availability. The nitrogen in raw, coarse bone is extremely slow in its action. The removal of fat by steaming or boiling makes the nitrogen of bone more available. The availability of the nitrogen of bone is also closely in proportion to its fineness of division.

(*7*) *Horn and Hoof-Meal* have been shown to possess about the same rapidity of action as finely ground dried fish.

(*8*) *Leather* varies in its rapidity of action according to its condition. Raw leather is practically valueless as a source of nitrogen for plants. *Roasted* and *steamed* leather has a little more value than raw leather, but is comparatively valueless. However, the nitrogen in finely ground leather that has been carefully treated with sulphuric acid has a degree of availability about equal to that of ground fish.

(*9*) *Cottonseed Meal and Castor-Pomace*, finely ground, furnish nitrogen that is utilized by plants in about the same degree as ground fish or even dried blood.

Various experiments have been made to determine the comparative plant-food value of nitrogen in the more common animal and vegetable materials. While the results have not been uniform, they serve as a fair guide. Taking results secured with nitrate-nitrogen as 100, the following table can be made.

Table Showing Comparative Plant-Food Value of Nitrogen in Animal and Vegetable Materials.

	Availability or crop producing value.
Nitrate of soda,	100
Dried blood,	70
Cottonseed-meal,	70
Castor-pomace,	70
Fish, dried and ground,	68
Horn and hoof meal,	68
Dissolved leather,	65
Steamed,	15
Roasted leather,	10
Raw leather,	2

It must be understood that the above figures are only approximate and are not of universal application. They indicate what is fairly true when used on the same crop under the same conditions. To illustrate, if by the application of fifty pounds of nitrate-nitrogen we were able to increase a wheat crop 100 pounds an acre, the application of the same amount of nitrogen in the form of dried blood, cottonseed-meal or castor-pomace would increase the crop seventy pounds an acre; the increased yield from use of dried fish, horn and hoof meal would be sixty-eight pounds; from raw leather, two pounds, etc.

(*b*) *Availability of Different Forms of Phosphoric Acid.*

The availability of phosphate compounds as plant-food depends upon several conditions, among which may be mentioned:

(1) The form of compound, (2) the kind of material, (3) the fineness of division, (4) the character soil, and (5) kind of crop.

(*1*) *The Availability of Phosphoric Acid Dependent on Form of Compound—The water-solubles* form of phosphates is readily distributed in the soil and is immediately absorbed and used by roots as plant-food. Therefore, water-soluble phosphates present in dissolved rock, superphosphates. dissolved bone, etc., represent the form most quickly available.

The *citrate-soluble or reverted* form of phosphates does not dissolve easily in pure water, but does dissolve fairly well in soil water and in the acid plant-juices contained in and exuded by the rootlets. The disadvantage in using reverted phosphate is, that on account of its slow solubility it is not quickly, thorough and uniformly distributed through the soil, and consequently does not come so easily into contact with the roots of plants.

The *insoluble* form of phosphates, like ground rock, is not easily available under ordinary conditions.

(2) *Availability of Phosphoric Acid Dependent on Kind of Material Furnishing it.*—Mineral phosphates untreated are changed into soluble forms very slowly under usual conditions and they become available as plant-food much less easily and quickly than do phosphates contained in animal or vegetable matter. In organic matter, as bone for example, the phosphates are associated intimately with material that decays easily and, in the process of such decay or rotting, the phosphate compounds are more or less changed and made soluble.

(3) *Availability of Phosphate Compounds affected by Fineness.*—It has been found in usual practice that the phosphate compounds, especially of organic matter, are more quickly available as they are more finely ground. Increased fineness increases the rapidity with which the phosphate compounds can be acted upon and rendered soluble by natural agencies.

(4) *Availability of Phosphate Compounds affected by Kind of Soil.*—Soils containing an abundance of decaying organic matter usually favor the more rapid change of insoluble to soluble phosphates. On muck soils the application of undissolved rock in the form of "floats" gives about as good results as the dissolved phosphate. The insoluble phosphates contained in the soil may be made gradually available by keeping the soil well supplied with humus together with occasional liming.

(5) *Availability of Phosphates Influenced by kind of Crop.*—Different plants have been found to show varying degrees of power to appropriate the same kind of plant-food. For example, fine-ground insoluble phosphate rock may be utilized to a greater or less extent by wheat, barley, corn, peas and turnips, while beans and potatoes do not seem benefited. Turnips especially appear to thrive just as satisfactorily on the fine undissolved as on the dissolved rock. When a crop can advantageously use a cheaper form of plant-food, it is economy to use that form.

(c) *Availability of Different Forms of Potash.*

There is little difference between the different compounds of potash in respect to the readiness with which plants use them as food. Muriate of potash dissolves a little more readily and is distributed through the soil somewhat more quickly than sulphate of potash.

Preferences Shown by Plants for Different Forms of Food.—It is a fact of great interest and importance, that one form of a fertilizing constituent is preferred by some plants to the same constituent in another form. This preference is indicated by greater yield or better quality of product or by both. The most striking instance is the effect of potash salts upon tobacco crops. The quality of tobacco is injured by potash in the form of muriate and, hence, only sulphate should be used for fertilizing purposes. The quality of sugar beets and of potatoes often appears to be better when sulphate of potash is used.

Much investigation in this interesting field remains yet to be made. The facts now known are meagre, but so far as known they should be utilized. Whenever a plant shows any marked preference for any special form of food, we should supply that particular form if practicable.

Economy in Purchasing Different Forms of Plant-Food.—Other things being equal, we can effect considerable saving in purchasing fertilizing materials by a careful selection based upon a study of market values.

The most expensive form in which nitrogen is usually purchased is that of sulphate of ammonia. When highgrade sulphate of ammonia sells for $60 a ton, each pound of nitrogen in it costs about fifteen cents. When high-grade nitrate of soda sells for $40 a ton, each pound of nitrogen in this form costs about twelve and one-half cents. As between these two forms, the nitrogen of one is two and one-half cents a pound cheaper than the nitrogen of the other, and it will, therefore, be found more economical to use nitrate of soda rather than sulphate of ammonia, when special circumstances do not require the use of the latter. Dried blood, containing thirteen per cent. of nitrogen, at $36 a ton furnishes nitrogen at an approximate cost of fourteen cents a pound. The nitrogen in fish-scrap may cost somewhat less. In such forms as wool-waste, ground leather and hair, nitrogen may be purchased at much less, but these forms are not usually economical at any price.

The cheapest possible manner in which farmers can provide their crops with nitrogen is by means of such plants as clover. These plants can supply themselves with nitrogen from the air, and can thus store up nitrogen for future use in the soil. Nitrogen supplied in this way can be made, to a considerable degree, to take the place of the nitrogen of commercial fertilizers, and at a greatly diminished cost. By such means the use of the most expensive of fertilizing materials can be greatly diminished and much saving effected.

Soluble phosphoric acid can in general be more cheaply purchased in the form of dissolved rock than in the form of dissolved bone or bone-black.

Muriate of potash costs less than sulphate, and is, therefore, more economical when its use answers one's purpose. With the exception of a few crops, like tobacco, sugar beets, and potatoes, muriate of potash can nearly always be used to advantage. Potash in the form of carbonate, as found in wood-ashes, is apt to be somewhat expensive. When ashes contain five per cent. of potash and two per cent. of phosphoric acid and cost $10 a ton, each pound of potash costs about eight cents, while in the form of muriate of sulphate, the cost would be about one-half. It is easily conceivable, however, that on acid and certain other soils the use of ashes might prove economical. The only way of telling with absolute certainty whether ashes will prove more economical than other forms of potash is to make an actual trial.

In applying fertilizers, bulk is often desirable, but in *purchasing commercial fertilizers, the object should be to secure as much nitrogen, potash and phosphoric acid in available forms as possible for one dollar, instead of as many pounds as possible of fertilizer, regardless of the amount of plant-food contained in it.* This is particularly applicable to mixed fertilizers, which at present form the larger proportion of fertilizers sold in this State. Since there is smaller bulk to handle in mixing, a smaller number of packages for holding, and, consequently, less weight and freight, it is, as a rule, more economical to purchase fertilizers in their more concentrated forms. For illustration, it is more economical to purchase one ton of a high-grade fertilizer than three tons of a low-grade fertilizer, one ton of the former containing the same amount of plant-food contained in three tons of the latter; because, in making the latter, three times as much labor is involved in mixing the goods, three times as many packages are required and three times as much freight must be paid, all for the same amount of plant-food.

5. Which is More Advantageous, to Purchase Complete Fertilizers or to Purchase Separate Ingredients?

The question of home mixing of fertilizers is now being much discussed. Not a few farmers have adopted the plan of purchasing unmixed ingredients and mixing them at home. When a farmer once tries this method, he rarely purchases a ready-mixed complete fertilizer after that. It is pertinent in this connection to consider both sides of the question, both the advantages and disadvantages of purchasing unmixed fertilizing ingredients.

Economy.—The average retail price of a ton of mixed fertilizer is from $8 to $9 above the market value of its unmixed ingredients. This difference represents the cost of mixing, freight, profit, etc. It is readily seen that a portion, at least, of the difference can be saved by purchasing unmixed ingredients. Many farmers who have done their own mixing, estimate that the mixing costs them seventy-five cents a ton on an average. In mixed fertilizers, a pound of nitrogen costs the farmer, on an average, about twenty cents, while he ought to be able to purchase it in the very best forms at a total cost not to exceed fifteen cents. Available phosphoric acid and potash in mixed fertilizers cost farmers six to seven cents a pound, and they can usually be purchased unmixed for three and three-fourths to four and one half cents, total cost.

Definite Knowledge of Materials Used.—When separate materials are purchased, the farmer can more closely ascertain whether his goods are what they claim to be. Ground leather cannot be passed for nitrate of soda, sulphate of ammonia, etc. In mixed goods it is not easy to detect inferior articles. The chances are that the farmer will get better materials in unmixed than in mixed goods, although this would not be true in dealing with the most reliable manufacturers.

Variation of Mixture to Suit Different Crops.—By careful observation and experiment in the manner previously described, the farmer can change his mixture so as to adapt it more nearly to the needs of his crops and soil. Manufacturers claim to manufacture goods which are specifics for different crops. But it is noticed that the special mixtures for the same crop, as made by different manufacturers, vary quite as much as do mixtures for different crops. For illustration, taking forty different potato-manures in the market, we find that they vary in nitrogen from 1.50 to six per cent.; in available phosphoric acid, from 4.75 to eleven per cent.; and in potash, from 2.50 to 11.50 per cent.; and yet each claims to be exactly adapted to the needs of the potato crop. We have met with instances where the manufacturer used the same formula as a special for different crops whose needs were quite unlike. It is safe to say that, without any experience, the farmer can hit the needs of his soil and crops by mere guess quite as closely as do some of the complete fertilizers. The farmer can ascertain what particular forms and quantities of materials are best suited to his needs by means of simple experiments.

Educational Value.—There is little of educational value in using an unknown mixture. To purchase intelligently unmixed fertilizing materials will ultimately lead in most cases to a well-grounded knowledge of the science of agriculture. One will seek to know what the different forms of plant-food are, what they do, from what sources they can be obtained, and how he can use them to best advantage. He will become to some extent an investigator, and will, of necessity, take a deeper interest in his work. His entire system of farming will be lifted to a higher plane and his more intelligent labor will yield more profitable results.

The chief disadvantages connected with purchasing separate materials are the following: (1) On small purchases little or no reduction of price is made. This may often be true, but in such cases it is easily possible for farmers to combine and order larger lots. (2) It is claimed that, owing to lack of proper facilities, the farmer cannot make mixtures that will be even and fine. So far as actual results go, it is found that farmers can and do make mixtures which are, on an average, very satisfactory in their practical working as compared with mixtures of manufacturers.

It has been represented to farmers that peculiar virtues are imparted to the elements of plant-food by proper mixing and that this proper mixing can be accomplished only by means not at the command of farmers. Such statements are misrepresentations, based either upon the ignorance of the person who makes them or upon his anxiety to sell mixed goods. Nitrate of soda, for illustration, does its work in plant nutrition in exactly the same manner whether it is added to the soil as part of a mixture or whether the ingredients of the mixture are applied separately. The availability of plant-food is not usually affected by mixing. Other conditions determine whether a fertilizer shall be applied in mixed form or in separate materials.

6. To What Extent Home-Mixing is Practicable.

The conveniences needed to do one's own mixing are the following: A tight barn floor, or earth floor that is hard, smooth, dry and under cover; platform scales, shovel, iron hand-rake or hoe and a sand-screen. Farmers are advised, if they do their own mixing, not to attempt to treat bones or rock with sulphuric acid (oil of vitriol) but to purchase their superphosphate from the manufacturer.

The advantages connected with having the mixing of fertilizers done at a factory are the following: First, the mixing is apt to be more thoroughly done at the factory. Second, the factory should be able to do mixing in large quantities more economically, since it has all facilities required. As a rule, it costs the farmer from $2.50 to $3.00 to have the mixing and rebagging done at a factory for each ton of materials.

When the farmer prefers to purchase separate materials and do his mixing at home, the following suggestions may be helpful: If one has purchased the different materials in the right weights, such as he wants to use for mixing, then no weighing is necessary, as he has simply to mix all the materials he has. If he makes different mixtures, then the different materials should be weighed accurately. If the material is at all lumpy, it should be sifted with a sandscreen, the lumps separated and then pulverized before being added to the pile of fine material. When the materials have been thus prepared, the most bulky material is spread out upon the floor in an oblong pile that varies from six to ten inches in depth. The top is leveled off and then a layer of the next material is put on, not quite so thick, and so on until the different constituents have been added to the pile, care being taken to make such material cover the one under it evenly over the whole surface. Then, one should commence at one end and shovel over the pile, reaching clear to the bottom every time. After mixing well, the mixed portion is passed behind. When the whole pile has been treated once in this way, then the mixed pile is leveled, swept up around the edges and again treated in the same manner. This process should be repeated three or four times. Any lumps noticed at any time should be thoroughly broken up. If greater thoroughness is desired, the mixture may be sifted or screened before sacking. It is convenient to weigh into sacks which will hold from 100 to 150 pounds. One should take great pains to purchase his materials in finely powdered and perfectly dry condition, if he plans to mix the materials at home.

7. Special Suggestions Relating to the Purchase of Separate Fertilizing Ingredients.

In addition to what has been already stated, there are some other suggestions which it is well to heed in connection with the purchase of separate fertilizing materials.

Purchase High-Grade Materials.—It will almost invariably be found more economical to purchase high-grade fertilizing materials.

In *applying* fertilizers, bulk is often desirable, but in *purchasing* commercial fertilizers, the object should be to secure as much nitrogen, potash and phosphoric acid in available forms as possible for one dollar, instead of as many pounds as possible of fertilizer, regardless of the amount of plant-food contained in it.

Fineness and Dryness of Fertilizers Important.—Fertilizers can not, as a rule, be in too finely powdered condition nor can they be too dry. With many materials, bone for example, the availability as plant-food is directly dependent upon the fineness of division. Two commercial fertilizers containing the same amount of plant-food in the same forms may differ considerably in respect to the availability of that food and, consequently, in respect to their agricultural value, if one is coarsely and the other finely ground. Excessive moisture in fertilizers is undesirable on several grounds. First, the larger the amount of moisture, the smaller will be the amount of plant-food in a ton. Second, excess of moisture causes the particles to stick together and is likely to result in caking and in clogging when used in drills. Third, an excess of moisture favors the decomposition and loss of nitrogen in many forms of organic matter. This is shown by the fact that some fertilizers give off a very offensive odor if allowed to become damp, while they are comparatively free from disagreeable odors if they are thoroughly dry. A strong odor in a fertilizer is an indication that organic matter is decomposing and nitrogen is being lost and indicates weakness and loss rather than strength as a fertilizer.

Taking Advantage of Fluctuating Prices.—By watching the market variations, it is possible to save more or less. It often happens that lower prices prevail during that part of the year when the farmer has most leisure. In any case, where home-mixing is practiced, it should be done before the beginning of the busy season. It is well for farmers early in winter to enter into correspondence with three or four different parties to ascertain the prices at which they can purchase the plant-food materials they desire.

Purchase of Plant-Food Materials According to "Unit" System and According to Ton System.—The more common method employed by farmers in purchasing fertilizers, whether mixed or unmixed, is to pay a given price for a ton of goods without particular reference to the guaranteed composition, that is, the amount of plant-food contained in them. In purchasing such high-grade materials as nitrate of soda, sulphate of ammonia, dried blood, potash salts, etc., the composition is fairly uniform and one may usually feel safe in purchasing by the ton. However, in a variable material like tankage, for instance, it is unwise to purchase by the ton, at least without a guarantee.

The "unit" system is based on actual amounts of plant-food contained in the goods purchased. A unit of plant food is one per cent. for one ton, that is, twenty pounds. A unit of nitrogen is twenty pounds of nitrogen, a unit of available phosphoric acid is twenty pounds of available phosphoric acid, and a unit of actual potash is twenty pounds of actual potash. In quoting prices a dealer might offer sulphate of potash at $1.00 per unit of actual potash (twenty pounds). That would mean five cents a pound. This is the most satisfactory system of purchasing, for the consumer pays for just the amount of plant-food he buys.

Making Club-Fertilizers.—In some towns farmers club together and purchase their separate ingredients, each one doing his own mixing himself. In other cases the club decides upon a definite formula and sends out specifications to manufacturers for furnishing the same already mixed and sacked, letting the contract to the lowest responsible bidder. One of the most successful instances of this sort is the Riverhead Town Agricultural Society of Long Island. They have found that a fertilizer containing four per cent. of nitrogen, eight per cent. of available phosphoric acid and ten per cent. of actual potash is well adapted to their conditions for growing potatoes and vegetables. They require the nitrogen to be distributed in three different forms, one-half being fish-scrap; one-fourth, nitrate of soda; and one-fourth, sulphate of ammonia. The potash must be in form of muriate. For the season of 1899 they were able to get 1,000 tons or more of this mixture made at $24.80 a ton. Commercial fertilizers of similar composition sold for $36 to $40 at the same time. The actual saving effected by the members of this club amounts to not less than $10,000 a year. At the above price nitrogen cost them 11.7 cents a pound, available phosphoric acid 3.6 cents a pound and potash as muriate 3.75 cents a pound. It will be noticed that these prices are a little more than one-half those paid for plant-food by the average farmer purchasing mixed fertilizers in the ordinary way. The members of this club paid $24.80 for each ton of fertilizer, which would have cost farmers, buying at the average prices paid for plant-food in mixed fertilizers $38.64.

Where to Purchase Unmixed Materials.—Any large manufacturer of fertilizers will generally fill orders for separate ingredients. Farmers are advised to write to three or four different firms and get their prices. In comparing prices, one should take into consideration the question of freight. The schedule of prices given later may be used as a general guide in regard to what one should pay for different forms of materials.

Farmers will find their chief difficulty in knowing in what forms and quantities to order separate fertilizer constituents.

The suggestions found in subsequent pages giving this information in regard to our more common crops will be found helpful.

8. Methods and Seasons of Applying Fertilizers.

The method to be used in applying a fertilizer depends primarily upon the efficiency with which the constituents of the fertilizer are distributed most thoroughly and uniformly throughout the portion of soil where the plant roots are. The effect of a fertilizer is lost so far as it does not reach the plant roots. Pains must be taken to secure even and complete distribution of fertilizers on or in the soil, since it is desired to have the food reach every plant in the field. In order to distribute small quantities of concentrated fertilizers over a broad area, it is well to dilute by mixing with some such substance as dry earth, road-dust, sifted coal-ashes or sand.

Drilling and Broadcasting.—As between applying fertilizers with the drill or by broadcasting, the best results are given sometimes by one and sometimes by the other method, according to the crop and special conditions. Labor is saved by using the drill, while the best ultimate results appear more often to come from broadcasting, ploughing or harrowing in accordance to circumstances. When a fertilizer is especially needed by a crop in its earliest stages, there is advantage in drilling it in with the seed. When concentrated fertilizers are to be distributed broadcast, it is desirable that they should be somewhat diluted to promote uniform distribution. When a concentrated fertilizer is drilled in, great pains must be taken to keep the fertilizer from coming into direct contact with the seed, because many of the commercial fertilizing materials will injure the seed if brought into direct contact. Drilling has the advantage of placing the plant-food just where the rootlets of the young plant can use it in the early stages of growth, when they most need it. Where the root system is small and is confined to rows or hills some distance apart, drilling may use less plant food than broadcasting for an equally good crop.

Distribution of Soluble Fertilizers.—Materials which are readily soluble can be scattered over the surface. After the first fall of rain they distribute themselves throughout the soil very completely and uniformly. Such materials are nitrate of soda, sulphate of ammonia, soluble phosphates and soluble potash salts. These materials are preferably used in case of top-dressing.

Distribution of Fertilizers not Readily Soluble.—Materials which are not readily soluble are preferably well mixed through and beneath the soil. Thus, dried blood, bone-meal, fish scrap and similar materials are best placed at greater or less depth beneath the soil, because under these conditions they become soluble more rapidly and are retained more surely by the soil. However, the mistake should not be made of working such materials into the soil too deeply, because their plant-food may be lost by leaching and carried down beyond the reach of the roots.

Time of Application.—Fertilizers which dissolve easily and diffuse through the soil rapidly, and which are not readily retained by the soil, are best applied only when the crop is ready to utilize them. If put on too early, there is danger of their being leached from the soil and carried more or less beyond the reach of the plant and thus lost. Nitrates and, to a less extent, ammonia compounds come under this precaution. Hence, it is not wise ordinarily to apply guano, ammonia compounds or nitrate of soda in the fall, except in climates which have a dry fall and winter. Their application should be deferred until spring. In wet springs, ammonia compounds are preferably applied rather than nitrate of soda; or, if nitrate of soda is used, loss may be avoided by making several small applications, instead of one at the start. Care should be taken, however, not to make applications of nitrate of soda too late in the season, as the maturing of the crop will be retarded and there will be an excessive growth of stems and leaves.

Fertilizers which do not dissolve readily or which do not diffuse through the soil rapidly are better applied to the land before the crop commences its growth. To this class belong stable-manure, bone-meal, dried blood, tankage, cottonseed-meal, ground rock, and to some extent, soluble phosphates and potash compounds.

Special Precautions.—In applying highly concentrated commercial fertilizers, it is wise to prevent the fertilizer coming in contact with the seeds or foliage of plants.

Fertilizers containing ammonia compounds should not be mixed with wood-ashes, lime, or Thomas slag (odorless phosphate), since some of the ammonia is likely to be lost.

On soils of loose texture and small retentive power, it is best to use, for the most part, those forms of fertilizers which are not too easily soluble, in order to make as small as possible the losses occasioned by heavy rains. Animal and vegetable materials are especially suited for such cases.

9. The Most Advantageous Methods of Using Farm-Produced Manures.

Under this head we will discuss some of the more common points relating to the use of stable-manure in its application to different soils and crops.

Amount of Application.—In applying stable-manure to soils, it may be kept in mind, as a general guide, that a ton of good stable-manure approximately contains:

Ten pounds of nitrogen,
Five pounds of phosphoric acid, and
Ten pounds of potash.

From one-half to two-thirds of this plant-food should become available during the first season.

When stable-manure is applied alone, five tons an acre may be suggested as the smallest amount to use. The exact amount will vary, of course, with the condition of soil and the kind of crop. Ten tons an acre ought to be sufficient for general farm crops. It is more economical to apply smaller amounts at more frequent intervals. The frequent use of light applications of stable-manure keeps the soil in a more uniform condition of fertility and the nitrogen is utilized more fully and with less loss. It is not infrequent that farmers apply twenty tons of stable-manure to one acre of land. This means 200 pounds of nitrogen, 100 pounds of phosphoric acid and 200 pounds of potash. Very few farm crops can possibly make use of so much plant-food in one season.

Stable-Manure Supplemented by Commercial Fertilizers.—It will probably be found true in most cases that the greatest good can be derived from farm-manures by supplementing them by commercial fertilizers. While this is true of most crops, it is particularly true of garden crops where large amounts of plant-food are required. To give a roughly approximate idea, we might say that for every ton of stable-manure applied, it would be well to use with it from 50 to 100 pounds of acid phosphate and from 25 to 50 pounds of high grade muriate or sulphate of potash. This is best accomplished in the manner described on page 55.

Use of Fresh Manure.—The statements below apply to fresh manure containing only small amounts of coarse litter. It appears to be the prevailing belief both in the theory and practice that best results are ordinarily secured by applying stable-manure to the soil in as fresh condition as possible. Mixed with the soil, fresh manure decomposes readily, having its own constituents made more available as plant-food, and, moreover, rendering available some of the insoluble plant-food previously in the soil. In this way losses from destructive forms of fermentation, leaching, etc., are mainly prevented.

Fresh manure gives better results than rotted manure on heavy clay soils, when one desires to lighten the condition of the soil. However, when one desires direct fertilizing action promptly, fresh manure gives sufficiently quick returns on light soils, becoming available as fast as the plant needs it, if the season is not too dry. On heavy clay soils, manure decomposes slowly and the constituents of fresh manure may not become available as fast as needed. On this account, it may happen that on heavy soils little benefit is seen from the application of fresh manure until the second season after its application.

In dry hot seasons an excessive application of fresh stable manure tends to "burn out" the soil, this tendency being more noticeable in light than in heavy soils.

Fresh manure used alone and in large quantities, has a tendency to favor rapid growth of foliage and stems at the expense of fruit and grain. It is, therefore, more suitable for grasses, forage plants and leafy crops than for grains, when used exclusively and liberally.

Such crops as potatoes, sugar beets and tobacco appear to be injured in quality by the direct application of stable-manure. However, on some soils, usually heavy ones, it can be used satisfactorily in growing sugar beets. It is advised in such cases to apply the manure in the fall previous to the spring in which the crops are to be put in, thus allowing time for a considerable amount of decomposition; or it may be applied to corn, following this with the crop liable to be injured by direct application.

When fresh stable-manure contains much coarse, undecomposed litter, it is better not to apply it until the coarse portion has become more or less decomposed.

Use of Rotted Manure.—In half rotted manure, the fertilizing constituents, as a whole, are in readily available form for the use of plants. Such manure is less bulky and more easily distributed than fresh manure. For the improvement of the mechanical condition of a soil, the best results come from using rotted manure on light soils. It must, however, be remembered that on such soils there is more or less danger that some portion of the valuable fertilizing constituents may be leached out and lost. On this account it is found advisable to apply such manure to light soils only a short time before it is needed by the crop. In general, rotted manure is better adapted to spring applications. It is better to apply rotted manure on light soils at frequent intervals in small amounts.

In warm, moist climates, it makes much less difference whether the manure is applied in fresh or rotted condition. In cold climates, however, the use of decomposed manure is preferable.

Methods of Application.—Three methods of applying manure on the field are in common practice. We will briefly consider each of these:

(*a*) *Applying in Heaps.*

By this method the manure is distributed in heaps over the field and permitted to lie some time before being spread. This method is objectionable for several reasons. The labor of handling is increased; there is danger of loss from decomposition and leaching; the manure is not uniformly distributed, the spots beneath the heaps being more thoroughly manured on account of the leaching. Storing manure in very large heaps is less objectionable, provided the heap is carefully covered with earth and not allowed to lie too long.

(*b*) *Applying Broadcast.*

By this method the manure is spread more or less completely and evenly on the field, being plowed in at once or allowed to lie some time on the surface. This is preferably practiced on the level field, where there is little danger from surface washing. In late fall and early spring, there is likely to be very little loss of nitrogen. On a loose soil, there may be loss from leaching, if the manure is spread long before the crop is put into the soil; but in average experience, this is not apt to be considerable. This method has the advantage of uniform distribution as the liquid portion is evenly by degrees mixed with the soil. When the manure is leached of its soluble nitrogen compounds, it does not decompose so readily. On this account it is well, in case of light or porous soils, to plow the manure in as soon as spread.

In regard to the depth at which manure should be plowed in, it is safe to say that in very compact soils, the depth should not be greater than four inches, while in lighter soils the depth may be increased. It is important that the manure be near enough the surface to allow access of sufficient moisture and air, in order that decomposition may not be too much delayed.

It will probably be found most economical for the average farmer to draw the manure as produced directly to the field, and spread it instead of letting it pile up about the barns or in the barnyard.

(*c*) *Applying in Row.*

This method has the advantage of placing the manure where it will reach the plant most quickly and of enabling one to use smaller amounts than in broadcasting. It is especially applicable for forcing some garden crops. Rotted manure gives good results when used this way.

10. The Use of Green-Manures.

Definition.—The term "green-manures," properly used, means any crop grown chiefly with the object of improving the soil, and not for securing the harvested product.

Leguminous Crops or "Nitrogen Gatherers" as Green-Manures. — Those plants belonging to the legume or clover family have the power to secure a large part of their nitrogen from the air. When these are turned under the soil as green-manures, they add nitrogen to the soil. The nitrogen brought into the soil in this manner is in a form that tends to decompose rapidly and thus furnish plant-food for other crops. It must be kept clearly in mind that these nitrogen-gathering crops can not be successfully grown unless the soil contains an abundance of phosphoric acid, potash and lime. The crop absorbs only such mineral plant-food as it finds in the soil and it is a serious mistake to suppose that any green crop adds anything to the mineral plant-food of the soil. It may make more available for other crops the phosphoric acid and potash compounds already existing in the soil. Therefore, in growing green crops there should generally be liberal applications of phosphoric acid and potash and often also of lime.

The crops that have been found most efficient as nitrogen-gathering green-manures are red clover, crimson clover, cow peas, and soja beans. The clovers tend to improve the physical condition of the soil also, sending down their roots to considerable depths. They are able also to get considerable food from the subsoil. These are marked advantages in their favor in addition to their power to get nitrogen from the air.

The amount of nitrogen these crops draw from the air depends upon the amount of nitrogenous and other plant-food in the soil. The richer the soil is in nitrogen, the less the crop takes from the atmosphere. In order, therefore, to utilize leguminous crops to best advantage as nitrogen-gatherers, the soil should contain only small amounts of available nitrogen, but generous amounts of mineral plant-food. Under favorable conditions a clover crop will take from the air an amount of nitrogen equal to fifty pounds or more per acre. It is possible by continuous growth of leguminous crops to accumulate an excess of nitrogen in the soil, unless there is added an abundant supply of mineral plant-food.

With judicious management in growing clover or some other leguminous crop for use as green manure, it is easily possible to supply the nitrogen for one's crops without purchasing this, the most costly plant-food element.

"Nitrogen-Consuming" Crops as Green-Manures.—Crops other than leguminous plants are used as green-manures, the more common ones being rye and buckwheat. These crops do not possess the power of using atmospheric nitrogen. All the nitrogen they use comes directly from the soil. They do not, therefore, add any nitrogen to the soil, but rather they take available nitrogen from the soil and change it to less available forms. Such crops do not increase the fertility of the soil and can not be used as a substitute for leguminous crops or commercial forms of plant-food. The principal advantages coming from the use of these crops as green-manures are two: First, they furnish an abundance of vegetable matter that becomes useful in supplying humus-making material; second, they serve as cover crops, thus preventing loss of plant-food by leaching. In order to grow these crops well, one must make sure that they have an abundance of plant-food of all kinds.

11. Rotation of Crops.

General Principles Underlying Rotation of Crops.—The general object of systematically growing different crops successively on the same soil is to utilize the plant-food in the soil most economically, and maintain the soil in condition for raising maximum crops. The system of rotation to be followed must depend upon the kind of soil and character of farming. A fruit grower and a dairyman would follow different systems of rotation. Continuous growth of one crop on the same field is most exhaustive of plant-food, as a rule, and, in addition, the physical conditions of the soil deteriorate.

In working by a system of crop rotation, certain general facts should be kept in mind and carried into practice, principal among which are the following:

(*a*) *Use of Remains of Preceding Crop.*—The system of rotation should be such as to utilize to the best advantage any plant-food material furnished the soil by the preceding crop. Thus, after a crop of clover, it is better to grow wheat and then oats rather than the reverse, because the wheat has less power than oats to utilize plant-food. If oats were grown first, wheat might be at a disadvantage unless additional plant-food were furnished. In general weak-feeding crops, unless specially fed, should precede strong-feeding crops in rotation, so that the former may have the first chance at the more available forms of plant-food.

(*b*) *Keeping Soil in Good Mechanical Condition.*—Each class of crops exercises a specific action upon the mechanical condition of soils. Grass crops tend to make a soil compact; grain and hoed crops tend to make the soil open and porous. It is desirable that these conditions should be gradually alternated somewhat. The amount and frequency of loosening and compacting must depend upon the character of the soil. Sandy soils need more of those crops that compact, while heavy clay soils need those crops that will keep it more open. Rotation of crops should have reference to these conditions and aim at the best mechanical condition.

(*c*) *Alternation of Deep-rooted and Shallow-rooted Crops.*—By including in a system of rotation crops that have both deep and shallow root systems, the plant-food is not taken entirely from the surface soil but more or less from the subsoil. By such treatment the soil is exhausted less quickly and requires less frequent applications of plant-food. Then, again, in many soils the potash and lime are largely in the subsoil, the phosphoric acid and nitrogen being mainly in the surface soil. The growing of deep-rooted crops also exercises a beneficial effect upon the mechanical condition of the soil.

(*d*) *Alternation of Nitrogen-gathering and Nitrogen-consuming Crops.*—The value of nitrogen-gathering crops as green manures has been already considered. In a four or five year rotation system, the use of a leguminous crop like clover will, with one good application of stable-manure, maintain the soil nitrogen undiminished. In all systems of rotation some nitrogen-gathering crop should be included as an absolute essential.

(*e*) *Rotation of Crops to Maintain Humus.*—The humus of the soil is gradually used up, when hoed and grain crops are continuously grown and this loss of humus may seriously change the physical and plant-food conditions of the soil. The supply of humus may be kept up by use of stable-manure and green crops, and this fact should be kept in mind in every system of rotation.

(*f*) *Use of Farm and Commercial Manures in Rotation.*—It is safe to say that economical results will attend the application of farm-manures to the land once at least in a rotation of four or five years. Most of the nitrogen needed in addition can be supplied by clover. The balance of feeding will come mostly in the line of phosphoric acid and potash. When commercial fertilizers are used, they will be most beneficial applied to those crops known as weak-feeding.

12. The Use of Lime on Soils.

Carbonate of lime, slaked-lime and quicklime perform four definite functions when applied to soils: (1st) They furnish lime as plant-food when it is lacking; (2d) they render available the insoluble forms of nitrogen and potash in the soil; (3d) they lighten heavy soils and compact light soils; and (4th) they neutralize the acidity of sour lands. One disadvantage in using quicklime or slaked-lime on soils to be used in growing potatoes is that scabby potatoes are likely to be produced.

How to Ascertain a Soil's Need of Lime.—Put in a cup a tablespoonful or more of soil and moisten with water enough to make a thick paste. After letting it stand ten or fifteen minutes, insert into the soil a piece of blue litmus paper, of any convenient size, say two inches long and half an inch wide, inserting about half of it into the soil. Litmus paper can be purchased at any drug store. Allow the litmus paper to remain in the soil two minutes or longer. Then take the litmus paper from the soil carefully without tearing, rinse off the soil with water, and observe whether it is still blue or has become clearly red. If the paper has become clearly red, the soil is acid and the application of lime will be likely to benefit many crops. Be careful not to handle with the fingers the end of the litmus paper that goes under the soil, previous to making the test.

This test may be supplemented by an actual field trial, using beets for a crop, carrying the work out as directed on page 64.

How Much Lime to Apply and How Often.—The general rule may safely be followed of applying lime in smaller quantities at more frequent intervals than large quantities once in several years. In the case of light and dry soils, the range of application would be from fifteen to thirty bushels of quicklime per acre, according to the conditions of need. On heavy clay soils and on rich soils, the application may vary from twenty-five to seventy-five bushels.

In rotations of five or six years, one liming will probably suffice for the rotation under ordinary conditions. On meadows kept in grass for many years and fertilized exclusively by commercial fertilizers, liming on the surface once in five years may be helpful.

When to Apply Lime.—Autumn is the best time to apply lime on land used for spring crops. It must be kept in mind that quicklime is injurious to many crops, but its power to injure plants is gradually lost by lying in the soil. In case of autumn seeding, the lime can be scattered after plowing and then harrowed in very thoroughly. For many crops, lime may be applied in the spring with little risk, provided it is worked into the soil very completely. In case of very sour soils, the application of lime in the spring is often very beneficial.

What Form of Lime and Use.—Of the various forms of lime, it will probably be found that quicklime will prove cheapest, as it is the most concentrated form. This is especially true when the material has to be freighted and drawn some distance.

How to Apply Lime to the Soil.—Owing to the large lumps usually contained in quicklime, it is not best to attempt to spread it directly upon the soil as this method would not enable one to secure a uniform distribution. The following method will insure more even distribution. The freshly burned lime is placed in heaps twenty feet apart, the amount in each pile depending on the rate of application. Twenty-pound heaps would make about one ton an acre. The heaps are well covered with soil. If the earth is moist, the lime will absorb moisture enough to fall into a fine powder in a few days at most. In case the soil is very dry, throw half a pail of water or less over each heap before covering it with earth. As soon as the lime has become slaked, it should be spread from the heaps as evenly as possible and then plowed under or preferably harrowed in at once, because the lime is liable to cake with the soil and not yield the best results.

13. Plant-Food Mixtures for Different Crops.

We will now consider in a more specific manner the quantities of different forms of plant-food that can be applied to advantage to one acre of land for different crops.

We must make it clearly understood at the start that no rigidly fixed formulas can be given for any crop on all soils. The question of quantity of application and of proportion must always, in the very nature of the case, remain more or less a matter of individual experiment. Every field is constantly changing in the extent and character of its needs. The farmer must constantly study results and let the experience of one year suggest to him his plan for the year following. With this preliminary precaution, it may be of interest to consider briefly what has ordinarily been the method of procedure in determining the proportions of nitrogen, phosphoric acid and potash in making fertilizers for different crops.

In making formulas, it was first proposed to make the formula correspond to the analysis of the plant. This method was practiced for some time, when it was found that there was already in the soil more or less available plant-food and that fertilizing material was often applied where one or more constituents could be omitted or reduced in quantity. It was then suggested that soil analysis should form the basis of determining the needs of the soil in different crops, but this failed to produce satisfactory results. The formulas at present used by many have been based, in part, upon the composition of the plant and, in part, upon the actual field-tests.

The amount of nitrogen called for by analysis of plants is generally reduced, because we can depend upon the soil to furnish a considerable amount. In case of leguminous crops, the amount of nitrogen which we need to supply can be reduced to a small fraction of what the plant will use, because such crops can draw their main supply of nitrogen from the air.

The amount of soluble phosphoric acid is ordinarily increased above what plant analysis calls for, because the solubility is more or less decreased after the fertilizer comes into contact with the soil.

The formulas given in the pages following have been drawn from such various sources as could be considered reliable.

It will be noticed that, in giving the amount of fertilizer material to put on one acre of land, a variable rather than a fixed amount is given. To illustrate, instead of prescribing 100 pounds of nitrate of soda for a certain crop, we give the amount as "100 to 200 pounds." This means that, if the land is in good condition, 100 pounds may answer, but if in poor condition, more should be used up to 200 pounds. Thus, it will be seen that even with the most specific directions that can be given, much must be left to the individual for experiment.

The materials which are given for use in the following pages are assumed to have a fairly definite composition and our calculations are based on the following conditions of composition:

(1) Nitrate of soda, 95 to 96 per cent. pure, containing 16 per cent. of nitrogen.

(2) Dried blood, containing 10 per cent. of nitrogen.

(3) Sulphate of ammonia, containing 20 per cent. of nitrogen.

(4) Stable-manure, containing .5 per cent. of nitrogen, one-half available at once.

(5) Cottonseed-meal, containing 7 per cent. of nitrogen.

(6) Bone-meal, containing 20 per cent. of total phosphoric acid, one-half being calculated as available during first season of application; also containing 4 per cent. of nitrogen.

(7) Dissolved bone, containing 15 per cent. of available phosphoric acid and 3 per cent. of nitrogen.

(8) Dissolved bone-black, containing 15 per cent. of available phosphoric acid.

(9) Dissolved rock, containing 15 per cent. of available phosphoric acid.

(10) Muriate of potash, 80 per cent. pure, containing 50 per cent. of potash.

(11) Sulphate of potash, 90 to 95 per cent. pure, containing 50 per cent. of potash.

(12) Kainit, containing 12 to 13 per cent. of potash.

(13) Wood-ashes, containing 5 per cent. of potash.

To make the foregoing statements in different form, we can say, approximately:

One pound of Nitrogen is furnished by

Five pounds of sulphate of ammonia, or
Six and one-fourth pounds of nitrate of soda, or
Ten pounds of dried blood, or
Fourteen pounds of cottonseed-meal, or
Twenty-five pounds of high-grade bone meal, or
Two hundred pounds of good stable-manure.

One pound of Phosphoric Acid is furnished by

Five pounds of bone meal, or
Six and three-fourth pounds of dissolved bone-black, dissolved bone, or dissolved rock.

One pound of Actual Water-soluble Potash is furnished by

Two pounds of sulphate of potash, or
Two pounds of muriate of potash, or
Eight pounds of kainit, or
Twenty pounds of unleached wood-ashes.

It should be undertsood that the materials given in the following mixtures may not furnish the elements of plant-food in the cheapest form. The point of cost must be determined by each individual farmer for himself at the time he makes his purchases.

Alfalfa.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	1	5 to 10	30 to 60 pounds nitrate of soda; 1 to 2 tons half-rotted stable manure.
Available Phosphoric acid,	8	30 to 60	200 to 400 pounds dissolved rock.
Potash,	10	50 to 100	100 to 200 pounds muriate of potash.

Suggestions.—The quantity given above is intended as an annual surface application after the crop has been started. It may be well to lime the ground thoroughly the fall before putting in the crop. The soil should have an abundance of plant-food when the crop is put in and it is recommended at this time to make the following application: Sixty pounds nitrate of soda, 100 pounds of dried blood (or 150 pounds of cottonseed-meal), 500 pounds of dissolved rock, and 400 pounds of muriate of potash. The soil needs to be in the best condition of tillage when putting in a crop of alfalfa and this may be readily secured by previous growth of some crop that requires considerable cultivation. In such case, a part of the fertilizer can be applied to the preceding crop.

Apples.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.	Pounds of Different Materials for One Tree.
Nitrogen,	2	8 to 16	25 to 50 pounds nitrate of soda; 40 to 80 pounds dried blood.	½ to 1 pound nitrate of soda; ¾ to 1½ pounds dried blood.
Available phosphoric acid.	8	30 to 60	200 to 400 pounds dissolved rock.	4 to 8 pounds dissolved rock.
Potash,	12	50 to 100	100 to 200 pounds muriate of potash, or 1,000 to 2,000 pounds wood-ashes.	2 to 4 pounds muriate of potash, or 20 to 40 pounds wood-ashes.

Suggestions.—The growing of apples and similar fruits is a case of continuous cropping of the same character on the same soil and is thereby attended with greater exhaustion of plant-food than where rotations can be practical. The amount of plant-food to be applied and the age when such feeding should begin must depend upon the soil. On soils naturally good, feeding the trees should begin as soon as the trees commence bearing. On poor soils the largest quantities given above should accompany the setting of the trees, and then the smaller quantities be added every year. On poor and light soils, green manuring can be carried on advantageously for awhile. Whenever green manuring is used, the crop should be turned under early in the spring. On soils in good condition, green manuring should not be practiced too continuously. Overfeeding fruit trees with nitrogen must be carefully avoided, as this tends to produce excessive growth of wood, too succulent in character to be hardy, and it also seriously interferes with fruit production.

As the roots of the tree feed through a long growing season, those forms of plant-food can often be used which become available gradually. In place of the mixture given above, one can use the following:

One hundred pounds cottonseed-meal.
One hundred pounds fine bone-meal.
One hundred pounds dissolved rock.
One hundred pounds muriate of potash.

In applying plant-food annually to fruit trees, it should be put on early in the spring and plowed in. It should be remembered that the feeding roots are situated in the lower layers of the soil, and the plant-food should therefore be placed as near the roots as practicable, especially with young trees. If plant-food that is not easily soluble is placed entirely on the surface of the soil, there will be a tendency on the part of the feeding roots to grow near the surface, and under such conditions, the trees will more easily suffer from drought. In case easily soluble forms of plant-food are used, surface application will give good results.

With increasing age and larger yields of fruit, the amount of plant-food applied may be increased to advantage.

Asparagus.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	20 to 40	60 to 120 pounds nitrate of soda; 50 to 100 pounds dried blood; 75 to 150 pounds cottonseed-meal.
Available phosphoric acid,	8	40 to 80	200 to 400 pounds bone meal; 150 to 300 pounds dissolved rock.
Potash,	10	50 to 100	100 to 200 pounds muriate of potash.

Suggestions. —In fertilizing asparagus, three facts are to be kept in mind. First, the yield and market value of the crop depend upon the number and size of the shoots; second, the size of the shoots depend upon a large and vigorous growth of tops later in the season, by which nutritive materials are stored up in the roots for the use of the succeeding crop; and, third, the successful growth of the asparagus depends, in large measure, upon proper feeding. Moreover, the length of life of an asparagus bed depends greatly on its feeding.

The asparagus crop grows during the entire season and hence is able to use, to some extent, some of the slower acting forms of plant-food. It is essential that a part of the plant-food shall be present in quick-acting forms, so that it may be used at once in promoting growth of shoots at the time, and the residue in less soluble forms will continue to feed the crop during the rest of the growing season, thus enabling the plant to store up available nutrition in the roots for use of the crop the year following.

In setting asparagus roots, the soil should be carefully prepared and heavily fertilized. The largest quantities given above and even more will be found desirable. A generous application of half-rotted stable-manure supplemented by phosphates and potash is good at this time. Stable-manure may also be applied every two or three years in the fall, in addition to the plant-food formula given above.

After the first year the amounts of plant-food prescribed should be liberally applied fairly early in the spring. After one begins to cut shoots, it may be well, in addition to this early application, to use at the close of the cutting season 100 pounds of nitrate of soda, 200 pounds dissolved rock and 100 pounds of muriate of potash, or 400 pounds of kainit in place of muriate. The exact amounts to use must be governed by individual experience.

Barley.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	12 to 24	25 to 50 pounds nitrate of soda; 20 to 40 pounds sulphate of ammonia; 40 to 80 pounds dried blood.
Available phosphoric acid,	7	20 to 40	150 to 300 pounds dissolved rock.
Potash,	8	25 to 50	50 to 100 pounds muriate of potash.

Suggestions.— Barley is a strong-feeding crop and can utilize forms of food not easily available for wheat. Excessive application of nitrogen compounds is to be avoided, when barley is grown for grain. Large applications of stable-manure should not be applied directly to the crop on this account, but may be used safely on the crop preceding barley in a rotation.

When barley is grown with peas as a forage crop, much larger amounts of quickly available nitrogen can be used with advantage.

Beans.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	1	5 to 10	25 to 50 pounds dried blood; 35 to 70 pounds cottonseed-meal.
Available phosphoric acid,	7	30 to 60	200 to 400 pounds dissolved rock.
Potash,	9	35 to 70	70 to 140 pounds muriate of potash.

Suggestions.—The formula given above applies to beans grown for the seeds. When beans are grown to be eaten green, as for string-beans, more nitrogen should be applied, as this tends to develop foliage and tender pods and retard ripening. For such purpose the following mixture may be used: 100 pounds nitrate of soda, 100 pounds dried blood, 150 pounds cottonseed-meal or fine ground fish-scrap, 500 pounds dissolved rock, and 175 pounds of muriate of potash.

Beets.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	20 to 40	125 to 250 pounds nitrate of soda.
Available phosphoric acid,	8	25 to 50	175 to 350 pounds dissolved rock.
Potash,	10	50 to 100	100 to 200 pounds muriate of potash.

Suggestions.—This application is intended to apply to beets grown for early market for table purposes. The mixture given above may be used at time of seeding, and this followed by applications of nitrate of soda as a top dressing once in ten days at the rate of fifty pounds an acre for three or four weeks after the plants are well started. This insures rapid and constant growth, under favorable weather conditions, and enables one to secure the higher prices of the earliest product.

In growing *sugar beets*, the aim is to secure the largest amount of sugar possible, and this can be greatly influenced by the kind of plant-food given. The following mixture can be used for one acre: 125 pounds nitrate of soda, 100 pounds sulphate of ammonia, 400 pounds dissolved rock, and 150 pounds sulphate or muriate of potash. For best results it is well to apply only about one-third of this mixture before sowing, then another third after the plants are well up, and the remainder before the first or second cultivation. Excess of nitrogen tends to produce rapid growth with large roots and small proportions of sugar of low purity. The foliage should have an early and rapid growth because the leaves are essential to the formation of sugar. It is not desirable to use slow-acting forms of plant-food and thus prolong the growth after the plant should give itself largely to sugar production.

For *fodder* purposes, the aim is to grow as large a crop as possible. Hence in growing beets for fodder, the plant-food should be so planned as to secure a continuous and prolonged growth, rather than early and rapid growth. The following mixture may be used for one acre: sixty pounds nitrate of soda, 200 pounds dried blood, 150 pounds fish scrap or cottonseed-meal, 400 pounds acid phosphate and 180 pounds muriate of potash.

Blackberries.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	3	15 to 30	25 to 50 pounds nitrate of soda; 50 to 100 pounds dried blood; 100 to 200 pounds cottonseed-meal.
Available phosphoric acid,	6	30 to 60	200 to 400 pounds dissolved rock.
Potash,	8	40 to 80	80 to 160 pounds sulphate of potash.

Suggestions.—An abundance of potash and phosphoric is desirable in order to secure a strong and plentiful growth of cane. Moderate acting forms of nitrogen are preferable for the most part.

Buckwheat.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	2	10 to 20	60 to 120 pounds nitrate of soda.
Available phosphoric acid,	6	30 to 60	200 to 400 pounds dissolved rock.
Potash,	5	25 to 50	50 to 100 pounds muriate of potash.

Suggestions.—Buckwheat can supply itself from forms of plant-food not readily available. It is often grown on the poorer soils of a farm on this account. Frequently phosphoric acid alone gives marked results. Large application of nitrogen must be avoided as this produces a large growth of straw with little grain.

Cabbage.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	40 to 80	60 to 120 pounds nitrate of soda; 200 to 400 pounds dried blood; 150 to 300 pounds cottonseed-meal or ground fish.
Available phosphoric acid,	8	80 to 160	500 to 1,000 pounds dissolved rock.
Potash,	10	100 to 200	200 to 400 pounds muriate of potash.

Suggestions.—The cabbage crop is one of the heaviest feeding crops. In addition to the amount of plant-food stated above, it will often be found most advantageous to apply a top dressing of 100 pounds of nitrate of soda and 200 pounds dissolved rock per acre after the plants have been transplanted and well started in growth. Later, when the heads begin to form, another 100 pounds or more of nitrate of soda per acre may be applied as a top dressing.

Carrots.

Same as for beets grown for fodder purposes.

Cauliflower.

Same as for cabbage.

Celery.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	40 to 80	125 to 250 pounds nitrate of soda; 100 to 200 pounds dried blood; 150 to 300 pounds cottonseed-meal or ground fish.
Available phosphoric acid,	8	80 to 160	500 to 1,000 pounds dissolved rock.
Potash,	10	100 to 200	200 to 400 pounds muriate of potash.

Suggestions.—The above mixture should be used when the plants are set. This may be followed at intervals with a top dressing of 100 pounds of nitrate of soda per acre. On muck soils rich in available nitrogen, special feeding of nitrogen is not equally important. Abundance of water is a great essential for celery in addition to other forms of plant-food. Abundance of soluble nitrogen, other conditions being favorable, promotes rapidity of growth, which is attended by the high market qualities of crispness and sweetness.

Cherries.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	2	10 to 20	25 to 50 pounds nitrate of soda; 60 to 80 pounds dried blood.
Available phosphoric acid,	7	35 to 70	250 to 500 pounds dissolved rock.
Potash,	9	45 to 90	90 to 180 pounds muriate of potash.

Suggestions.—It is desirable that in addition to the amounts of plant-food given, an abundance of lime shall be kept in soil where cherries are grown.

Clover.

Same as for alfalfa.

Corn.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	2	10 to 20	50 to 100 pounds dried blood; 75 to 150 pounds cottonseed-meal or ground fish.
Available phosphoric acid,	7	35 to 70	250 to 500 pounds dissolved rock.
Potash,	6	30 to 60	60 to 120 pounds muriate of potash.

Suggestions.—Corn is a vigorous feeder. In can follow a clover crop with advantage. It is not injured like many grain crops by heavy applications of stable-manure, but, when fertilized by stable-manure, phosphoric acid should be applied also. Corn usually leaves soils in good physical condition for following crops. Phosphoric acid appears in practice to be of special value in growing corn.

The application given above is intended for corn grown as a field crop for the grain. When corn is grown as a *forage* crop, double the amount of nitrogen given above may be used. When corn is grown for *silage*, the following mixture may be applied: 150 pounds of dried blood, 200 pounds of cottonseed-meal or ground fish, 350 pounds of dissolved rock, and 100 pounds of muriate of potash.

For *sweet corn*, a different object is sought. A green and succulent crop, in place of a matured one, is desired and earliness is usually a special object. The following mixture is suggested for sweet corn: seventy-five pounds nitrate of soda, 100 pounds of dried blood, 100 pounds of cottonseed-meal, 400 pounds of dissolved rock, and 150 pounds of muriate of potash.

Cucumbers.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	30 to 60	50 to 100 pounds nitrate of soda; 125 to 250 pounds dried blood: 125 to 250 cottonseed-meal or ground fish.
Available phosphoric acid,	6	50 to 100	350 to 700 pounds dissolved rock.
Potash,	8	75 to 150	150 to 300 pounds muriate of potash.

Suggestions. —This crop thrives best when humus is very abundant in the soil. Too much nitrogen is to be avoided, as there will be a tendency to excessive growth of vines and the fruit will also be large but of poor quality. However, in growing cucumbers for pickles, it may be desirable to use nitrogen and to use most of it in the quickly-acting form of nitrate as this will tend to cause a more abundant setting of fruit and a more rapid growth.

Currants.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	2	10 to 20	50 to 100 pounds dried blood; 75 to 150 pounds cottonseed-meal or ground fish.
Available phosphoric acid,	5	25 to 50	175 to 350 pounds dissolved rock.
Potash,	8	40 to 80	80 to 160 pounds muriate of potash.

Suggestions.—Regular feeding and cultivating adds very much to the yield of this crop. Excess of nitrogen in soils appears to render plants more easily subject to mildew.

Egg-Plant.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	40 to 80	100 to 200 pounds nitrate of soda; 125 to 250 pounds dried blood; 175 to 350 pounds cottonseed-meal or ground fish.
Available phosphoric acid,	5	50 to 100	350 to 700 pounds dissolved rock.
Potash,	9	90 to 180	180 to 360 pounds muriate of potash.

Flax.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	3	10 to 20	25 to 50 pounds nitrate of soda; 50 to 100 pounds dried blood.
Available phosphoric acid,	8	25 to 50	175 to 350 pounds dissolved rock.
Potash,	9	30 to 60	60 to 120 pounds muriate of potash.

Suggestions.—Flax requires its food to be in easily available forms and the soil must therefore be in good condition. Flax should be grown on the same land only once in four or five years, as the decay of the roots in the soil appears to form products injurious to the flax crop following. Stable-manure, when used, should be applied to the preceding crop.

Flowers and Flowering House-Plants.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	5	20 to 40	50 to 100 pounds nitrate of soda; 25 to 50 pounds sulphate of ammonia; 100 to 200 pounds cottonseed-meal.
Available phosphoric acid,	7	30 to 60	200 to 400 pounds dissolved rock.
Potash,	5	20 to 40	40 to 80 pounds muriate of potash.

Suggestions. —This mixture may be used for all kinds of flowering plants grown out of doors. Where flowering plants are grown out of doors only on a small scale, the above mixture can be applied at the rate of one ounce for three or four square feet. It would be well to apply one-third before planting or setting, working the fertilizer lightly into the surface soil; then another third after the plants are well up, and then the rest three or four weeks later. For flowering plants grown in a green house, the same mixture can be used; or, if desired, the phosphoric acid can be furnished in part by bone-meal. Apply liberally in soil at the start, and later, apply every week one-half ounce nitrate of soda to every ten square feet of soil surface and once in two weeks use for the same area one ounce of dissolved rock and one ounce of sulphate of potash.

For flowering plants *grown in pots*, as in the case of house plants, the above mixture may be used at the rate of half a teaspoonful for a six-inch pot once in two to four weeks, working slightly into the soil. For larger or smaller pots, use in proportion. For potted house plants, the following mixture may be used also, when it is desired to make up small quantities for use on only a few plants: Four ounces each of nitrate of soda, sulphate of ammonia and sulphate of potash and one pound of bone-meal. They should be purchased in powdered form and then carefully mixed together. Apply as directed above.

Foliage Plants.

Use the same mixture as given above for flowers, and in addition, apply nitrate of soda to the soil once in three or four weeks at the rate of one ounce for ten or twelve square feet. The nitrate of soda may be dissolved in water, one ounce to the gallon, and applied in solution. In applying it in this way be careful not to get the solution on the foliage but only on the soil.

Gooseberries.

Same as currants.

Grapes.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	2	16 to 32	50 to 100 pounds nitrate of soda; 75 to 150 pounds dried blood.
Available phosphoric acid,	8	60 to 120	400 to 800 pounds dissolved rock.
Potash,	12	100 to 200	200 to 400 pounds muriate of potash.

Suggestions.—Much of the nitrogen can be supplied by growing clover between rows and turning under. Excessive use of stable-manure is believed to produce a growth of weakened vitality, not able readily to withstand attacks of fungous diseases. Once in a few years lime may be applied to advantage.

Grass for Pastures.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	15 to 30	100 to 200 pounds nitrate of soda.
Available phosphoric acid,	8	30 to 60	200 to 400 pounds dissolved rock.
Potash,	10	40 to 80	80 to 160 pounds muriate of potash.

Suggestions.—It is possible to secure rich pasturage continuously in abundance only with a good supply of available plant-food. Three hundred pounds of the above mixture may be applied in the spring and an additional two hundred pounds in late summer, for the purpose both of getting a good growth and also of favoring the introduction of clovers.

Grass for Meadows.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	15 to 30	100 to 200 pounds nitrate of soda.
Available phosphoric acid,	7	30 to 60	200 to 400 pounds dissolved rock.
Potash,	9	35 to 70	70 to 140 pounds muriate of potash.

Suggestions.—The fact can not be too strongly emphasized that meadows from which the grass is cut year after year should be regularly fertilized every year in a liberal manner. Three hundred pounds of the above mixture may be applied in the spring and as much more soon after the hay is cut.

Grass for Lawns.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	5	20 to 40	125 to 250 pounds nitrate of soda.
Available phosphoric acid,	6	25 to 50	175 to 350 pounds dissolved rock.
Potash,	8	30 to 60	60 to 120 pounds muriate of potash.

Suggestions.—Where the soil is prepared for seeding, there should be a liberal application of plant-food, say 500 pounds or more of the above mixture. After the lawn is well started, an application of the above mixture at the rate of 100 pounds an acre in spring after the grass is well started, and once or more later in summer will suffice. Nitrate of soda alone gives good results applied two or three times as a top dressing during the season. In applying either the above mixture or nitrate of soda alone to grass, it will be well to dilute by mixing with muck, sifted ashes, or landplaster. Unless this is done, there is danger that the grass will be burned where the undiluted fertilizer comes in contact with the grass in considerable amounts.

Greenhouse Crops.

Same as for flowering plants grown in a greenhouse.

Hops.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	3	20 to 40	50 to 100 pounds nitrate of soda; 75 to 150 pounds dried blood; 75 to 150 pounds cottonseed-meal.
Available phosphoric acid,	6	35 to 70	250 to 500 pounds dissolved rock.
Potash,	12	80 to 160	160 to 320 pounds muriate of potash.

Suggestions.—Stable-manure supplemented by commercial forms of plant-food may be used to advantage.

Horse-Radish.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	15 to 30	50 to 100 pounds nitrate of soda; 75 to 150 pounds dried blood.
Available phosphoric acid,	6	25 to 50	175 to 350 pounds dissolved rock.
Potash,	9	35 to 70	70 to 140 pounds muriate of potash.

House Plants.

Same as for flowers and flowering house-plants and foliage plants.

Lettuce.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	5	40 to 80	100 to 200 pounds nitrate of soda; 150 to 300 pounds dried blood; 125 to 250 pounds cottonseed-meal or ground fish.
Available phosphoric acid,	6	50 to 100	350 to 700 pounds dissolved rock.
Potash,	9	75 to 150	150 to 300 pounds muriate of potash.

Suggestions.—Apply the above mixture at time of planting and when plants are well started use per acre 100 pounds of nitrate of soda as top-dressing. For growing lettuce under glass, see under greenhouse crops.

Millet.

Same as for meadow grass.

Muskmelons.

Same as for cucumbers.

Nursery Stock.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	3	10 to 20	25 to 50 pounds nitrate of soda; 100 to 200 pounds cottonseed-meal.
Available phosphoric acid,	6	25 to 50	175 to 350 pounds dissolved rock.
Potash,	7	30 to 60	60 to 120 pounds muriate of potash.

Suggestions.—An occasional liming is very desirable on many soils. When stable-manure is used, it should be applied in small quantities and supplemented by phosphoric acid and potash. Excess of nitrogen produces a rapid growth of wood, but such wood is too succulent to be strong and, it is believed, is more easily attacked by plant diseases.

Oats.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	12 to 24	75 to 150 pounds nitrate of soda.
Available phosphoric acid,	7	20 to 40	125 to 250 pounds dissolved rock.
Potash,	5	15 to 30	30 to 60 pounds muriate of potash.

Suggestions.—When oats are grown with peas for forage, it is advisable to use more phosphoric and potash than are indicated above.

Onions.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	5	50 to 100	100 to 200 pounds nitrate of soda; 200 to 400 pounds dried blood; 200 to 400 pounds cottonseed-meal.
Available phosphoric acid,	8	80 to 160	500 to 1,000 pounds dissolved rock.
Potash,	10	100 to 200	200 to 400 pounds muriate of potash.

Suggestions.—Additional applications of nitrate of soda at the rate of fifty pounds an acre may be made as a top-dressing twice after the crop is well started, at intervals of three weeks.

Fresh stable-manure is to be avoided on account of weed-seeds, and also a tendency to favor the growth of onion maggots. Stable-manure is preferably used in soil two years before planting onions. An excess of nitrogen delays the ripening and injures the keeping qualities of onions.

Parsnips.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	20 to 40	25 to 50 pounds nitrate of soda; 100 to 200 pounds dried blood; 100 to 200 pounds cottonseed-meal.
Available phosphoric acid,	8	40 to 80	300 to 600 pounds dissolved rock.
Potash,	10	50 to 100	100 to 200 pounds muriate of potash.

Peaches.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	2	15 to 30	25 to 50 pounds nitrate of soda; 50 to 100 pounds dried blood; 100 to 200 pounds cottonseed-meal.
Available phosphoric acid,	5	40 to 80	300 to 600 pounds dissolved rock.
Potash,	7	60 to 120	120 to 240 pounds muriate of potash.

Suggestions.—The application should be made early and worked into the soil. Much of the needed nitrogen may be furnished by means of clover crops grown between the rows of trees and turned under as green manure, but care must be taken not to accumulate an excess of nitrogen in the soil in this way, because this condition favors abnormal growth of wood and delays ripening of fruit.

Pears.

Same as for apples.

Peas.

Same as for beans.

Suggestions.—When peas are raised for picking green, larger amounts of nitrate of soda can be used to advantage.

Plums.

Same as for cherries.

Potatoes.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	30 to 60	50 to 100 pounds nitrate of soda; 50 to 100 pounds sulphate of ammonia; 200 to 400 pounds cottonseed-meal.
Available phosphoric acid,	8	60 to 120	400 to 800 pounds dissolved rock.
Potash,	10	100 to 200	200 to 400 pounds muriate or sulphate of potash.

Suggestions.—The use of stable-manure appears to favor the growth of potato-scab. When used, stable-manure should be applied to a preceding crop. Wood-ashes and lime are also reported to favor the attack of the scab.

Pumpkins.

Same as for cucumbers.

Quinces.

Same as for apples.

Radishes.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	15 to 30	50 to 100 pounds nitrate of soda; 75 to 150 pounds dried blood.
Available phosphoric acid,	8	35 to 70	250 to 500 pounds dissolved rock.
Potash,	10	40 to 80	80 to 160 pounds muriate of potash.

Raspberries.

Same as for blackberries.

Rhubarb.

Use same application as for lettuce, applying early in spring. About two weeks after beginning to cut for market, apply and cultivate into soil 100 pounds of nitrate of soda per acre and another equal amount after completing the cutting for the season.

Roses.

Same as for flowers.

Rye.

Same as for oats.

Suggestions.—Nitrogen is preferably applied in the form of nitrate of soda rather than stable-manure, and excessive use of nitrogen should be avoided, when crop is grown for grain. For forage and green manure, larger amounts of nitrogen are useful.

Sorghum.

Same as for corn.

Spinach.

Same as for lettuce.

Squashes.

Same as for cucumbers.

Strawberries.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	3	25 to 50	50 to 100 pounds nitrate of soda; 100 to 200 pounds dried blood; 100 to 200 pounds cottonseed-meal.
Available phosphoric acid,	7	55 to 110	375 to 750 pounds dissolved rock.
Potash,	9	75 to 150	150 to 300 pounds muriate of potash.

Suggestions.—Apply about 800 pounds of this mixture per acre before the plants are set. The next spring, preceding the first crop, make the same application. It may also be found good practice to apply top-dressing of nitrate of soda at the rate of 100 pounds an acre after the plants have blossomed.

Sugar Beets.

See under beets.

Tobacco.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	6	60 to 120	100 to 200 pounds nitrate of soda; 100 to 200 pounds sulphate of ammonia; 100 to 200 pounds dried blood; 200 to 400 pounds cottonseed-meal.
Available phosphoric acid,	6	60 to 120	400 to 800 pounds dissolved rock.
Potash,	10	100 to 200	200 to 400 pounds sulphate of potash.

Tomatoes.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	25 to 50	75 to 150 pounds nitrate of soda; 150 to 300 pounds dried blood.
Available phosphoric acid,	8	50 to 100	350 to 700 pounds dissolved rock.
Potash,	10	60 to 120	120 to 240 pounds muriate of potash.

Suggestions.—For early tomatoes apply the above mixture previous to or at the time of, setting plants. Three or four weeks later apply 100 pounds per acre of nitrate of soda, distributing around the hill. To make sure of even distribution this may be diluted with dirt, land-plaster, sifted coal ashes or similar material.

Turnips.

Same as for beets grown for fodder.

Watermelons.

Same as for cucumbers.

Wheat.

	Per cent.	Pounds for one acre.	Pounds of Different Materials for One Acre.
Nitrogen,	4	12 to 24	50 to 100 pounds nitrate of soda; 50 to 100 pounds dried blood.
Available phosphoric acid,	7	20 to 40	150 to 300 pounds dissolved rock.
Potash,	4	12 to 24	25 to 50 pounds muriate of potash.

PART IV.

THE ARITHMETIC OF FERTILIZERS.

When we desire to know the amount of nitrogen, potash and phosphoric acid contained in different forms and materials or to make up formulas from materials of known composition, or to determine the commercial value of any single material or of any mixture, it is necessary to go through various mathematical processes, most of which are comparatively simple and easily understood. So many inquiries are made about questions involving simple calculations, that it is thought advisable to present a somewhat systematic consideration of some of the more common problems met with. Some calculations, which it might be desirable to use at times, involve more knowledge of chemistry than can be given in a simple treatise of this kind.

Before taking up a consideration of the mathematical details, we will make a brief explanation of the different terms used in expressing fertilizer guarantees and analyses, because an accurate knowledge of such terms is important, especially in making commercial valuations and in planning formulas.

We shall, therefore, consider under the general head given above the following topics:

1. Explanation of terms used in stating guarantee-analyses of fertilizers.
2. Total constituents of fertilizers.
3. Commercial valuation of fertilizers.
4. How to calculate amounts of materials to be used in making home-made fertilizers.

1. Explanation of Terms Used in Stating Guarantee-Analyses of Fertilizers.

In examining the guarantee-analyses of different manufacturers, we find much variation in the terms used. Some forms are simple, stating only the most essential points, while others are complicated and confusing to the average farmer. We propose here briefly to explain all the different forms which are apt to be met. The following list contains most of the terms used in stating manufacturers' guarantee-analyses:

Nitrogen is expressed as

(a) Nitrogen, (b) ammonia, (c) nitrogen equal (or equivalent) to ammonia.

Phosphoric Acid is expressed as

(a) Phosphoric acid, (b) soluble phosphoric acid, (c) reverted phosphoric acid, (d) precipitated phosphoric acid, (e) available phosphoric acid, (f) soluble and available phosphoric acid, (g) insoluble phosphoric acid, (h) total phosphoric acid, (i) phosphoric acid equal (or equivalent) to bone phosphate of lime.

Potash is expressed as

(a) Potash, (b) potash (actual), (c) potash s. (or sul.), (d) potash (soluble), (e) potash as sulphate, (f) potash equal (or equivalent) to sulphate of potash, (g) sulphate of potash, (h) potassium oxide.

Nitrogen.

(a) *Nitrogen* is a gas and, in this form, can not be used in fertilizers. Therefore, whenever we speak of nitrogen in fertilizers, we do not mean that nitrogen exists in them as simple nitrogen. As previously stated, the nitrogen in fertilizers is always combined with other elements and may be present in one or more different forms; (1) in the form of nitrates, as nitrate of soda; (2) in the form of ammonia compounds, as sulphate of ammonia; and (3) in the form of organic matter, animal or vegetable, as dried blood, meat, tobacco stems, etc. Chemical analysis frequently does not ascertain and state in which form or forms the nitrogen is present in a fertilizer.

When, therefore, nitrogen is expressed in an analysis or guarantee simply as "nitrogen," it refers to the entire amount of nitrogen present without regard to the particular form or forms in which it is present.

(b) *Ammonia consists of nitrogen combined with hydrogen.* A pound of nitrogen will form more than a pound of ammonia, because the ammonia formed from a pound of nitrogen will contain that pound of nitrogen plus the necessary amount of hydrogen added to form ammonia. The chemical relations of nitrogen and ammonia are such that fourteen pounds of nitrogen, will unite with exactly three pounds of hydrogen, and will, therefore, produce just 17 pounds of ammonia; or one pound of nitrogen will make 1.214 pounds ammonia.

Manufacturers very commonly express the amount of nitrogen in the equivalent of ammonia, probably for the reason that, expressed as ammonia, larger figures are obtained than would be, if expressed as nitrogen; and the fertilizers appear to farmers to contain more nitrogen. While this method is in accordance with legal requirements and is entirely fair on the part of the manufacturers, *farmers should know that "nitrogen" and "ammonia" are not the same thing, since one pound of ammonia contains only about eight-tenths of a pound of nitrogen.*

(c) *Nitrogen equal (or equivalent) to Ammonia* is a form of expression which simply means that the nitrogen is stated not as nitrogen but as ammonia.

It would be better on every account if all guarantees stated simply nitrogen and never mentioned ammonia at all. As a matter of fact, compounds of ammonia are quite uncommon in commercial fertilizers, because nitrogen in this form is generally the most expensive and therefore least used. Strictly speaking, the term ammonia should never be used except when sulphate of ammonia or some similar compound is present in the fertilizer.

Phosphoric Acid.

(a) *Phosphoric Acid*, as used in connection with fertilizers, is a compound containing phosphorus and oxygen, which in fertilizers is found never by itself, but in combination with lime. Phosphoric acid stands for a certain amount of phosphate of lime. We may say roughly that one part of phosphoric acid is equivalent to about two parts of phosphate of lime. But we know that phosphoric acid exists in several different forms. (See page 40.)

(b) *Soluble Phosphoric Acid* represents the amount of phosphate of lime that dissolves easily in water. As explained already, soluble calcium phosphate is formed by treating with sulphuric acid some form of insoluble calcium phosphate, such as bones, bone-ash, South Carolina rock, etc. The phosphate thus formed is readily soluble in water.

(c) *Reverted Phosphoric Acid* is formed from soluble phosphoric acid under certain conditions into which we need not inquire here. Suffice it to say, that the soluble compound of phosphoric acid often changes, to some extent, on standing into a form, which, while less soluble, is still quite readily available as plant-food.

(d) *Precipitated Phosphoric Acid* is simply another name for the reverted form.

(e) *Available Phosphoric Acid* includes both the soluble and reverted forms of phosphoric acid, because both forms are available for the use of plants.

(f) *Soluble and Available Phosphoric Acid* is an expression which means the same as available.

(g) *Insoluble Phosphoric Acid* represents that form of phosphate of lime which is insoluble in water and ammonium citrate solution and which is of least value for agricultural purposes.

(h) *Total Phosphoric Acid* represents the entire phosphoric acid compounds without regard to the forms in which they exist. The total phosphoric acid is, therefore, the sum of the soluble, reverted and insoluble forms, or, to state it in another way, the sum of the available and insoluble forms.

(i) *Phosphoric Acid equal (or equivalent) to Bone Phosphate of Lime* is an expression which usually means nothing more or less than insoluble phosphoric acid. The expression is apt to be misleading, as it appears to imply that the phosphoric acid is derived from bone. It is applied probably to ground rock even more often than to bone. The expression is used often apparently for the sole purpose of misleading the farmer into thinking that the phosphoric acid has come from bone and also because, stated in this form, there appears to be twice as much phosphoric acid.

Potash.

(a) *Potash*, as used in connection with fertilizers, always means a compound containing potassium and oxygen, known as potassium oxide. Potash or potassium oxide is never found as such in fertilizers, but chemists use this form of expressing the results of analysis as a convenient standard for reference. Fertilizers generally contain potash in such forms as sulphate of potash, muriate of potash or carbonate of potash. Instead of stating the amount of sulphate, muriate or carbonate of potash present in a fertilizer, its equivalent amount is stated only in the form of potash in giving the results of analysis.

(b) *Potash Actual* is simply another expression for potash, as distinct from the sulphate, muriate, etc.

(c) *Potash S. (or Sul.)* means sulphate of potash. This is quite often used by manufacturers in giving guarantees. It is very misleading and, when used, is evidently employed for the purpose of making purchasers think that it is actual potash. One pound of potash is equivalent to 1.85 pounds of sulphate of potash; and so, in stating a guarantee as sulphate, the manufacturer makes it appear that his goods contain more potash than they really do.

(d) *Potash Soluble* represents the amount of potash that dissolves in water and is available for the use of the plants. The different forms of potash commonly used in fertilizers are readily soluble in water.

(e) *Potash as Sulphate* means simply sulphate of potash.

(f) *Potash equal (or equivalent) to Sulphate of Potash* is an expression which means simply sulphate of potash. When the potash is present as muriate, this expression should never be used.

(g) *Sulphate of Potash* signifies, or should signify, that this compound is actually present in the fertilizer and there is no muriate of potash present.

(h) *Potassium Oxide* means the same as potash or actual potash.

Advice Regarding Guarantee Analyses.—When a farmer purchases either a mixed fertilizer or separate fertilizing materials, he should purchase only under a guarantee of specified amounts of plant-food. Moreover, he should insist that the guarantee be in the following terms:

Nitrogen for all forms of nitrogen. An added statement as to whether the nitrogen comes from nitrate, ammonia compounds, dried blood, cottonseed-meal, etc., is desirable.

Available Phosphoric Acid or preferably water-soluble and reverted phosphoric acid separately for all forms of phosphoric acid.

Potash actual for all forms of potash, though it may be desirable to have stated *in addition* whether the potash is present as sulphate free from chloride or as muriate.

In examining a guarantee, pay attention only to the nitrogen, available phosphoric acid and actual potash, and require the guarantee to be in these terms before purchasing.

2. Total Constituents of Fertilizers.

If we add together the figures representing the different constituents of a fertilizer appearing in a chemical analysis (the nitrogen, the total phosphoric acid, and the potash), we shall find, as a rule, that the sum amounts to only 20 or 30 per cent. or pounds per hundred. The question often arises, "Why does the sum of the constituents in the analysis of a fertilizer amount to only 20 or 30 per cent., and what is the remaining portion, amounting to 70 or 80 per cent. made up of?" A few illustrations will, perhaps, suffice to make the matter clear.

High-Grade Fertilizers.—Taking a fairly high-grade fertilizer, we find by analysis that it contains:

	Per cent.
Nitrogen,	4
Available phosphoric acid,	8
Insoluble phosphoric acid,	2
Potash,	10

If the nitrogen comes from dried blood or meat, it will take about ten pounds of such material to furnish one pound of nitrogen. Since there are 4 per cent. of nitrogen, or four pounds of nitrogen in 100 pounds of fertilizer, it will take forty pounds of dried blood to furnish this amount of nitrogen. The amount of bone and sulphuric acid necessary to make a phosphate containing eight pounds of available phosphoric acid and two pounds of insoluble phosphoric acid would amount to about forty pounds. If the potash is present in form of high-grade sulphate, about twenty pounds of such sulphate would be required to be equivalent to ten pounds of potash. Tabulating the foregoing figures, we have the following:

	Pounds.
Dried blood required to furnish four pounds of nitrogen, ..	40
Bone and sulphuric acid required to furnish phosphates containing eight pounds of available and two pounds of insoluble phosphoric acid, ...	40
Sulphate of potash equivalent to ten pounds of potash, ...	20
Total, ...	100

In a fertilizer of this character, we can easily account for the entire amount of material.

Low-Grade Fertilizers.—Taking now a low-grade fertilizer, we find its composition to show:

	Per cent.
Nitrogen, ...	1
Available phosphoric acid, ...	5
Insoluble, ...	1
Potash, ...	1

We will suppose that the nitrogen and phosphoric acid come from the sources as indicated above and that the potash comes from kainit, eight pounds of kainit containing one pound of potash. Then we can tabulate our statement as follows:

	Pounds.
Dried blood required to furnish one pound of nitrogen, ...	10
Bones, etc., required to furnish five pounds of available and one pound insoluble phosphoric acid, ...	24
Kainit equivalent to one pound of potash, ...	8
Moisture, landplaster, dried earth, ground rock, etc., ...	58
Total, ...	100

We could, of course, vary the sources of materials used and get other figures, but these illustrations serve to give a fair idea of what a hundred pounds of fertilizer may be made, and why a statement of analysis does not account for more than twenty or thirty pounds of fertilizing materials in a hundred pounds of fertilizer.

3. Commercial Valuation of Fertilizers.

What is a Commercial Valuation of a Fertilizer? — The commercial valuation of a fertilizer consists in estimating the approximate value or money-cost of the essential fertilizing ingredients (nitrogen, phosphoric acid, and potash) in one ton of fertilizer.

In making a commercial valuation of a fertilizer, one uses either the figures given in the guarantee-analysis or preferably the figures given in the official state analysis, as a basis for calculation. This enables one to know how many pounds of nitrogen, of phosphoric acid and of potash there are in one ton of fertilizer.

The prices to be used in calculating a commercial valuation are furnished in a schedule prepared annually by experiment stations. This price-list for the year 1899 we give below.

Prices of Nitrogen, Phosphoric Acid and Potash Adopted by Experiment Stations.—The trade-values in the following schedule represent the average prices at which, in the six months preceding March the respective ingredients, in the form of unmixed raw materials, could be bought at retail for cash in our large markets, Boston, New York and Philadelphia. These prices also correspond to the average wholesale prices for the six months preceding March, plus about 20 per cent. in case of goods for which there are wholesale quotations.

It must be kept in mind that these trade-values are changing from time to time. In the fertilizer bulletins, which are issued by this Department, the latest trade-values are always given. Whenever in the following pages reference is made to the price-list, consult the latest.

SCHEDULE OF VALUES FOR FERTILIZER INGREDIENTS, 1899.

	Cents per pound.
Nitrogen, in ammonia salts,	15
in nitrates,	12½
in dry and fine ground fish, meat and blood, and in mixed fertilizers,	14
in cottonseed-meal and caster pomace,	14
in fine bone and tankage,	10
in coarse bone and tankage,	8½
Phosphoric acid, soluble in water, in bone fertilizers,	5
soluble in water, in rock fertilizers,	3
soluble in ammonium citrate, in bone fertilizers,	4½
soluble in ammonium citrate, in rock fertilizers,	2½
insoluble in ammonium citrate, in bone fertilizers,	2
Insoluble in ammonium citrate, in rock fertilizers,	1½

Phosphoric acid in fine bone, tankage and fish, ...	3½
Phosphoric acid in coarse bone and tankage, ...	2
Phosphoric acid in cottonseed-meal, castor pomace and wood ashes, ...	4½
Potash in high grade sulphate and in forms free from muriate (or chloride), ...	5
as muriate, ...	4¼

Potash in excess of that equivalent to the chlorine present, is to be valued as sulphate, and the remainder as muriate.

Nitrogen in mixed fertilizers is to be valued as derived from the best sources of organic nitrogen, unless clear evidence to the contrary is obtained.

Phosphoric acid in mixed fertilizers is valued at bone phosphoric acid prices, unless clearly found to be derived from rock phosphate.

Bone is sifted into two grades of fineness: Fine, less than 1-50 inch in diameter; coarse, over 1.50 inch in diameter.

The result obtained by the use of these valuations does not cover the items of mixing, bagging, freight and agents' commission.

Valuation and Cost of Fertilizers.—The total cost (to the farmer) of a ton of commercial fertilizer may be regarded as consisting of the following elements: (1) Retail cash cost, in the market, of unmixed trade materials; (2) cost of mixing and bagging; (3) cost of transportation; (4) storage, commissions to agents and dealers, selling on long credit, bad debts, etc. While the *total cost* of a fertilizer is made up of several different elements, a *commercial valuation* includes only the first of the elements entering into the total cost, that is, the retail cash cost in the market of unmixed raw materials.

Valuation and Agricultural Value.—The *agricultural value* of a fertilizer depends upon its *crop-producing power.* A commercial valuation does not necessarily have any relation to crop-producing value. For a particular soil and crop, a fertilizer of comparatively low commercial valuation may have a higher agricultural value; while for another crop on the same soil or the same crop on another soil the reverse might be true.

Simple Rule for Calculating Approximate Commercial Valuation of Fertilizers.

Multiply the per cent. of nitrogen by 3 and add to the product the figures representing the per cent. of available phosphoric acid and of potash. The sum expresses in dollars and cents the approximate commercial valuation of the fertilizer.

Example.—A fertilizer contains

	Per cent.
Nitrogen,	4.13
Available phosphoric acid,	8.52
Potash,	10.54

4.13 (per cent. of nitrogen) multiplied by three, equals,	$12 39
8.52 (per cent. of available phosphoric acid),	8 52
10.54 (per cent. of potash),	10 54
Total, per ton,	$31 45

If a fertilizer contains only one or two of the three essential fertilizing ingredients, the rule can be applied in a modified form. In case of fine bone-meal, use the total phosphoric acid in place of the available in making the calculation.

While this rule is not exact, it gives results that are fairly accurate and has the great advantage of simplicity. Results obtained by this rule will be somewhat higher than those given by the longer method of calculation. It will be found satisfactory commonly in making comparison of different mixed fertilizers.

For the benefit of those who desire a more exact method of calculating the commercial valuation of fertilizers, we give below a more detailed rule. But previously we give methods for calculating from one compound to another, and also methods for making valuations of unmixed fertilizing materials.

Rules for Calculating from One Compound into Other Compounds.

(*a*). *Compounds Containing Nitrogen.*

(1). *To change ammonia into an equivalent amount of nitrogen,* multiply the amount of ammonia by 0.82.

(2). *To change nitrogen into an equivalent amount of ammonia,* multiply the amount of nitrogen by 1.21.

(3). *To change nitrate of soda into an equivalent amount of ammonia,* divide the amount of nitrate of soda by 5 (or multiply by 0.20).

(4). *To change nitrate of soda into an equivalent amount of nitrogen,* divide the amount of nitrate of soda by 6 (or multiply by 0.165).

(5). *To change nitrogen into an equivalent amount of nitrate of soda,* multiply the nitrogen by 6.

(6). *To change sulphate of ammonia into an equivalent amount of ammonia,* divide the amount of pure sulphate of ammonia by 4.

(7). *To change ammonia into an equivalent amount of sulphate of ammonia,* multiply the amount of ammonia by 4.

(8). *To change nitrate of potash into an equivalent amount of nitrogen,* divide the amount of nitrate of potash by 7.2.

(*b*). *Compounds Containing Potash.*

(9). *To change muriate of potash into an equivalent amount of actual potash*, multiply the amount of muriate by 0.63.

(10). *To change actual potash into an equivalent amount of muriate of potash*, multiply the amount of actual potash by 1.6.

(11). *To change sulphate of potash into an equivalent amount of actual potash*, multiply the aomunt of sulphate of potash by 0.54.

(12). *To change actual potash into an equivalent amount of sulphate of potash*, multiply the amount of actual potash by 1.85.

(13). *To change nitrate of potash into an equivalent amount of actual potash*, multiply the amount of nitrate of potash by 0.46.

(14). *To change actual potash into an equivalent amount of nitrate of potash*, multiply the amount of actual potash by 2.15.

(*c*). *Compounds Containing Phosphoric Acid.*

(15). *To change bone phosphate into an equivalent amount of phosphoric acid*, multiply by 0.46.

(16). *To change phosphoric acid into an equivalent amount of bone phosphate*, multiply by 2.2.

Rules for Making Valuations of Unmixed Fertilizing Materials.

(*a*). *Materials Containing Nitrogen.*

(1) Sulphate of Ammonia. Rule. *Multiply the given per cent. of ammonia by 0.82 and this product by the price of one pound of nitrogen in the form of ammonia* (see price list on page 113). *Multiply this product by 20.*

Example: A sample of ammonium sulphate tests 24 per cent. ammonia; what is its commercial valuation?

24 per cent. of ammonia) × 0.82=19.68 per cent. of nitrogen.

19.68 × 15 cents = 295 cents, value of nitrogen in 100 pounds of ammonium sulphate.

295 cents × 20 = $59, value of nitrogen in one ton of ammonium sulphate.

(2) *Nitrate of Soda. Rule. Multiply the test per cent. of nitrate of soda by* 16½ *and this product by the price of one pound of nitrogen in the form of nitrates* (see price list on page 113.) *Multiply the last result by 20.*

Example: What is the valuation of one ton of nitrate of soda which tests 98 per cent.?

"Nitrate of soda testing 98 per cent." means that in every 100 pounds of material there are 98 pounds of pure nitrate of soda.

98 × 0.165 = 16.17 per cent. nitrogen in nitrate of soda.

16.17 × 12½ cents = 202 cents × 20 = $40.40 a ton.

When the per cent. of nitrogen is given, then the first step is omitted.

(*b*). *Materials Containing Phosphoric Acid.*

(1). *Available Guaranteed. Rule. Multiply the given amount of available phosphoric acid by the price of one pound of soluble phosphoric acid* (see price list on page 113) *and the result by 20.*

If the amount of insoluble phosphoric acid is given, multiply this by 40 and add to foregoing amount.

Example: What is the commercial valuation of one ton of dissolved bone-black testing 16 per cent. of available phosphoric acid?

16 × 4½ cents = 72 cents × 20 = $14.40 a ton.

If this sample were known also to contain 2 per cent. of insoluble phosphoric acid, then

2 × 40 cents = 80 cents and $14.40 + 0.80 = $15.20.

(2). *Bone Phosphate of Lime Guaranteed. Rule. Multiply the given amount of bone phosphate of lime by 0.46 and this product by the price of one pound of phosphoric acid in bone* (see price list on page 114).

Example: What is the commercial valuation of one ton of fine bone containing 50 per cent. bone phosphate of lime?

50 × 0.46 = 23, the per cent. of phosphoric acid in the bone.

23 × 3½ cents = 80.5 cents × 20 = $16.10 a ton.

(*c*). *Materials Containing Potash.*

(1) *Sulphate of Potash. Rule. Multiply the test per cent. sulphate of potash by 0.54 and the product by the price of one pound of potash in the form of sulphate* (see price list on page 114). *Multiply this product by 20.*

Example: What is the commercial valuation of one ton of sulphate of potash which tests 50 per cent. (low-grade) sulphate?

50 × 0.54 = 27 per cent. of actual potash.

27× 5 cents = $1.35, value of 100 pounds of sulphate of potash.

$1.35 × 20 = $27, value of one ton of sulphate of potash testing 50 per cent. sulphate.

Example: What is the valuation of one ton of sulphate of potash which tests 95 per cent. (high-grade) sulphate of potash?

95 × 0.54 = 51.3 per cent. of actual potash.

51.3 × 5 cents = 256.4 cents × 20 = $51.30 value of one ton of sulphate of potash testing 95 per cent. sulphate.

When the per cent. of actual potash is given, the first step can be omitted, and the per cent. of actual potash multiplied by the price per pound and then by 20.

(2) *Muriate of Potash. Rule. Multiply the given per cent. of muriate by 0.63 and the result by the price of one pound of potash in the form of muriate* (see price list on page 114). *Multiply this result by 20.*

Example: What is the valuation of one ton of muriate of potash testing 85 per cent. muriate?

85 × 0.63 = 53.55 per cent. of actual potash. 53.55 × 4 cents = 228 cents × 20 = $45.60 a ton.

Second Method for Making Commercial Valuations of Mixed Fertilizing Materials.

Rule. *Multiply the given per cent. of each constituent (nitrogen, phosphoric acid and potash) by its list-price, add the products and multiply the sum by 20.*

Example: What is the valuation of one ton of a commercial fertilizer having the following guarantee analysis?

	Per cent.
Nitrogen, ...	2 (to 3)
Available phosphoric acid, ...	8 (to 10)
Potash, ...	3 (to 5)

In each case where a guarantee analysis gives two figures, always use the lower, because the law takes only the lower guarantee into consideration.

	Cents.
Two (per cent. nitrogen) × 14 cents (price of 1 pound nitrogen) =	0.28
Eight (per cent. av. phos. acid) × 5 cents (price of 1 pound. av. phos. acid) = ...	0.40
Three (per cent. potash) × 5 cents (price of 1 pound potash) = ..	0.15
Total value of 100 pounds of fertilizers = ...	0.83

0.83 cents + 20 = $16.60 a ton.

When the nitrogen is given only in the form of ammonia, first change to equivalent of nitrogen (see (1) page 115) and then follow above rule.

When the phosphoric is given only in the form of bone phosphate of lime, first change to equivalent of phosphoric acid (see (c) (15) page 116) and then follow above rule.

When the potash is given only in the form of sulphate or muriate, first change to equivalent of actual potash (see (9) and (11) page 116) and then follow rule.

4. How to Calculate Amounts of Materials to be Used in Making a Home-Made Fertilizer.

There will probably be little demand for information in regard to quantities of different materials to be used in making home-made fertilizers, since the subject is treated in a specific manner on pp. 89-106. But it will, at least, be of interest to learn how different materials may be put together to make up a given formula.

Suppose that we desire to make one ton of a mixture containing

	Per cent.
Nitrogen,	4
Available phosphoric acid.	8
Potash,	10

Suppose, in addition, that we have on hand for our purpose the following materials:

Nitrate of soda containing 16 per cent. of nitrogen.

Acid phosphate containing 15 per cent. of available phosphoric acid.

Muriate of potash containing 50 per cent. of actual potash.

How many pounds of each of these materials shall we take to make one ton of a mixture having the composition given above?

To contain 4 per cent. of nitrogen, the ton must contain eighty pounds. The material which we use contains sixteen pounds of nitrogen in 100 pounds, and hence 500 pounds of nitrate of soda would be required to furnish eighty pounds of nitrogen.

To contain 8 per cent. of available phosphoric acid, the ton must contain 160 pounds. Our material contains in 100 pounds fifteen pounds of available phosphoric acid and hence 1067 pounds of acid phosphate would be required to furnish 160 pounds of available phosphoric acid.

To contain 10 per cent. of actual potash, the ton must contain 200 pounds. Our muriate of potash is one-half actual potash and hence 400 pounds of muriate would be required to furnish 200 pounds of actual potash.

We should, then, have the following amounts of materials to be used for one ton of fertilizer:

500	pounds nitrate of soda.
1,067	pounds acid phosphate.
400	pounds muriate or potash.

1,967 pounds of these mixed materials furnish the amounts of nitrogen, potash and phosphoric acid we need for one ton of our formula. How shall we make the mixture up to one ton? We simply add thirty-three pounds of sand, landplaster or other inert matter as a "filling," and we thus obtain one ton of a fertilizer having the composition given above.

By adding one more ton of filling, we should have two tons of a fertilizer of the following composition:

	Per cent.
Nitrogen,	2
Available phosphoric acid,	4
Potash,	5

PART V.

AVERAGE COMPOSITION AND VALUE OF DIFFERENT FERTILIZING MATERIALS AND OF FARM CROPS. TABULATED COMPILATION.

In the tables following, we present a compilation of data, showing the manurial composition and value of a large number of different kinds of materials. The different kinds of materials given are tabulated and presented under the following heads:

1. Materials used in fertilizers.
2. Hay and dry coarse fodders.
3. Green fodders.
4. Straw, chaff, leaves, etc.
5. Roots, bulbs, tubers, etc.
6. Grains and other seeds.
7. Mill products.
8. Fruits.
9. Vegetables.
10. Dairy products.
11. Farm animals and animal products.
12. By-products and waste materials.
13. Animal manures.

In assigning values to nitrogen, phosphoric acid and potash contained in materials not found regularly in the market as fertilizing materials, there is difficulty in fixing a price that will represent their real manurial value as compared with the most available farms common in the market. In the following tables the regular schedule values have been used for these materials that are recognized in the market and also for such materials as closely resemble any of these. For most vegetable materials, the price of nitrogen has been fixed at ten cents a pound, that of phosphoric acid and potash at four cents a pound. These are probably fair values, when we take the availability into consideration, and this should be done in order not to overestimate the fertilizing value of many materials.

1. Materials Used in Fertilizers.

	Pounds of nitrogen in 2,000 pounds of material.	Pounds of Phosphoric Acid in 2,600 Pounds of Material.			Pounds of potash in 2,000 pounds of material.	Approximate fertilizing valuation of 2,000 pounds.
		Available.	Insoluble.	Total.		
Apatite,	....	....	660 to 880	660 to 800	....	$13 00 to$16 00
Ashes (anthracite coal),	....	....	....	2 to 3	2 to 3	15 to 20
Ashes (bituminous coal),	....	....	....	8 to 10	8 to 10	50 to 70
Ashes (lime-kiln),	....	....	....	20 to 25	20 to 30	1 50 to 2 00
Ashes (spent tan-bark),	....	....	....	30 to 40	30 to 50	2 00 to 3 00
Ashes (wood, leached),	....	....	....	20 to 30	20 to 60	1 50 to 4 00
Ashes (wood, unleached),	....	....	....	30 to 40	80 to 160	5 00 to 10 00
Azotin (ground meat, etc., free from fat),	200 to 300	....	....	60 to 80	....	30 00 to 40 00
Bone-ash,	....	....	600 to 700	600 to 700	....	12 00 to 14 00
Bone-black,	....	....	500 to 700	500 to 700	....	10 00 to 14 00
Bone-black (dissolved),	....	240 to 360	10 to 20	260 to 360	....	10 00 to 15 00
Bone-meal,	70 to 90	80 to 160	320 to 340	400 to 500	....	26 00 to 32 00
Bone meal (free from fat),	100 to 120	100 to 120	300 to 380	400 to 500	....	30 00 to 36 00
Bone-meal (from glue factory),	30 to 40	120 to 160	320 to 400	440 to 560	....	22 00 to 28 00
Bone-meal (dissolved),	50 to 70	240 to 360	40 to 160	280 to 420	....	18 00 to 26 00
Carnallite,	....	....	....	....	260 to 280	11 00 to 12 00
Castor-bean pomace,	100 to 120	....	....	40 to 50	20 to 25	14 00 to 17 00
Cottonseed-hull ashes,	....	140 to 160	....	160 to 180	300 to 500	21 00 to 32 00
Cottonseed-meal,	120 to 140	....	....	40 to 60	30 to 40	17 00 to 21 00
Dried blood, red,	260 to 300	....	....	35 to 40	....	38 00 to 44 00
Dried blood, black,	120 to 240	....	....	40 to 80	....	28 00 to 36 00
Dried fish,	140 to 160	50 to 60	100 to 120	150 to 180	10 to 15	26 00 to 30 00
Florida rock,	....	....	500 to 800	500 to 800	....	10 00 to 16 00
Florida soft phosphate,	....	....	360 to 600	360 to 600	....	7 00 to 12 00
Hair,	280 to 320	....	....	....	....	8 00 to 10 00
Hoof-meal, horn-dust,	200 to 300	....	....	35 to 40	....	12 00 to 17 00
Kainit,	....	....	....	....	240 to 280	10 00 to 12 00
Keystone concentrated phosphate,	....	700 to 800	140 to 160	960 to 960	....	30 00 to 40 00
Krugite,	....	....	....	....	160 to 180	8 00 to 9 00
Leather-scraps, leather meal,	140 to 160	....	....	....	....	7 00 to 8 00
Lobster shells,	70 to 90	....	....	60 to 80	....	11 00 to 14 00
Marls (New Jersey greensand),	....	....	....	20 to 80	70 to 140	2 00 to 4 00
Meat-scraps,	200 to 240	....	....	40 to 60	....	30 00 to 36 00
Mud (fresh-water),	20 to 40	....	....	4 to 5	4 to 5	2 00 to 4 00
Muriate of ammonia,	500 to 520	....	....	....	....	75 00 to 78 00
Muriate of potash (80 to 85 per cent. pure),	....	....	....	....	1000 to1060	42 00 to 45 00
Nitrate of potash,	260 to 280	....	....	....	810 to 880	77 00 to 84 00
Nitrate of soda,	310 to 320	....	....	....	....	43 00 to 45 00
Nitrogenous guanos,	140 to 160	140 to 160	120 to 140	260 to 300	40 to 60	33 00 to 36 00
Oleomargarine refuse,	200 to 240	....	....	10 to 20	....	28 00 to 34 00
Peat,	15 to 20	....	....	1 to 2	2 to 4	1 50 to 2 00
Peruvian guano,	140 to 160	100 to 160	100 to 140	200 to 300	40 to 60	28 00 to 36 00
Soot from wood,	20 to 40	....	....	60 to 100	40 to 60	6 00 to 11 00
Soot from hard coal,	40 to 60	....	....	60 to 100	20 to 40	8 00 to 13 00
South Carolina rock (ground),	....	....	500 to 600	500 to 600	....	10 00 to 12 00
South Carolina rock (floats),	....	....	500 to 600	500 to 600	....	10 00 to 12 00
South Carolina rock (dissolved),	....	200 to 240	40 to 80	240 to 320	....	10 00 to 12 50
Sulphate of ammonia,	380 to 410	....	....	....	....	57 00 to 61 00
Sulphate of potash (low-grade,	....	....	....	....	560 to 600	28 00 to 30 00
Sulphate of potash (high-grade),	....	....	....	....	960 to1020	48 00 to 51 00
Sulphate of potash and magnesia,	....	....	....	....	520 to 560	26 00 to 28 00
Sylvinit,	....	....	....	....	300 to 320	13 00 to 14 00
Tankage, concentrated,	200 to 240	....	....	40 to 80	....	30 00 to 37 00
Tankage, crushed,	80 to 180	....	....	60 to 240	....	14 00 to 35 00
Tankage, garbage,	20 to 40	....	....	10 to 20	10 to 20	3 00 to 6 00
Thomas slag,	....	120 to 140	240 to 260	360 to 400	....	10 00 to 11 00
Tobacco stalks,	70 to 80	....	....	10 to 20	100 to 120	13 00 to 15 00
Tobacco stems,	40 to 50	....	....	10 to 20	140 to 160	11 00 to 13 00
Waste from powder works,	40 to 60	....	....	....	320 to 360	22 00 to 26 00
Wool-waste,	100 to 120	....	....	4 to 8	20 to 60	6 00 to 9 00

Hay and Dry Coarse Fodders—Green Fodders, Etc.

	Pounds of nitrogen in one ton.	Pounds of phosphoric acid in one ton.	Pounds of potash in one ton.	Approximate fertilizing valuation of 2,000 pounds.
2. Hay and Dry Coarse Fodders.				
Alfalfa,	44.0	10.6	34.0	$6 20
Blue mellot,	38.4	10.8	56.0	6 50
Buckwheat,	16.7	12.2	48.4	4 10
Buckwheat (Japanese),	32.6	17.0	66.4	6 60
Buttercups,	20.4	8.2	16.2	3 00
Clover (alsike),	46.6	14.0	40.2	6 82
Clover (Bokhara),	40.0	11.2	37.0	5 90
Clover (crimson),	40.0	7.6	25.0	5 30
Clover (mammoth red),	44.6	11.0	24.4	5 90
Clover (red),	42.0	10.0	40.0	6 20
Clover (white),	50 0	14.0	30.0	7 20
Corn fodder (with ears),	36.0	11.0	18.0	4 75
Corn (without ears),	22.4	6.0	28.0	3 60
Cow-pea (whole plant),	39.0	10.6	29.4	3 50
Daisy (white),	5.6	8.8	25.0	1 90
Daisy (ox-eye),	6.0	9.0	25.0	1 95
French rye-grass,	33.2	12.0	48.0	5 70
Hungarian grass,	24.0	7.0	26.0	3 70
Italian rye-grass,	23.0	11.0	25.0	3 75
June grass,	21.0	7.4	29.2	3 55
Kentucky blue grass,	23.8	8.0	31.4	3 95
Meadow fescue,	20.0	8.0	42.0	4 00
Meadow foxtail,	30.8	8.8	40.0	5 05
Millet (common),	25.6	10.0	34.0	4 30
Millet (Japanese),	22.2	8.0	24.4	3 50
Mixed grasses,	28.0	7.0	30.8	4 30
Mustard,	35.4	16.2	27.2	5 25
Oats (in bloom),	24.0	13.4	50.8	4 95
Orchard grass,	26.2	8.2	37.6	4 45
Pea (in bloom),	66.0	10.2	34.0	8 35
Perennial rye-grass,	30.8	12.8	40.0	5 20
Redtop,	23.0	7.2	20.4	3 40
Rowen of mixed grasses,	32.0	9.0	30.0	4 75
Sainfoin,	47.0	11.0	30.6	6 35
Salt marsh hay,	23.6	5.0	14.4	3 15
Serradella,	47.0	14.2	38.6	6 80
Soja bean (whole plant),	46.4	13.4	21.6	6 05
Tall meadow-oat grass,	23.2	6.4	34.4	3 95
Timothy hay,	25.2	9.2	30.6	4 10
3. Green Fodders.				
Alfalfa,	14.4	2.6	11.2	2 00
Buckwheat in blossom,	10.2	2.2	8.6	1 45
Clover (alsike),	8.8	2.2	4.0	1 15
Clover (crimson),	8.6	2.6	9.8	1 35
Clover (red),	10.6	2.6	9.2	1 55
Clover (white),	11.2	4.0	4.8	1 50
Corn fodder,	8.2	3.0	6.6	1 25
Corn fodder (ensilage),	5.6	2.2	7.4	95
Cow pea,	5.4	2.0	6.2	85
Flat pea,	22.6	3.6	11.6	2 55
Horse bean,	13.6	6.6	27.4	2 70
Hungarian grass (German millet),	7.8	3.2	11.0	1 35
Meadow-grass,	8.8	3.0	12.0	1 35
Millet (common),	12.2	3.8	8.2	1 70
Millet (Japanese),	10.6	4.0	6.8	1 50
Mixed pasture grasses,	18.2	4.6	15.0	2 60
Oat-fodder,	9.8	2.6	7.6	1·40
Peas,	10.0	3.6	11.2	1 60
Prickley comfrey,	8.4	2.2	15.0	1 50
Rape,	9.0	2.4	7.0	1 30
Rye-fodder,	9.8	4.5	14.0	1 70
Rye-grass (Italian),	10.8	5.8	22.8	2 20
Rye-grass (perennial),	9.4	5.6	22.0	2 05
Serradella,	8.2	2.8	8.4	1 25
Soja-bean,	5.8	3.0	10.6	1 10
Sorghum in bloom,	8.0	1.6	6.4	1 10
Timothy grass,	9.6	5.2	15.2	1 80
Vetch and oats,	4.8	1.8	15.9	1 20
White lupine,	8.8	7.0	34.6	2 55
Yellow lupine,	10.2	2.2	3.0	1 25
Young grass,	10.0	4.4	23.2	2 00

Hay and Dry Coarse Fodders—Green Fodders, Etc.—Continued.

	Pounds of nitrogen in one ton.	Pounds of phosphoric acid in one ton.	Pounds of potash in one ton.	Approximate fertilizing valuation of 2,000 pounds.
4. Straw, Chaff, Leaves, Etc.				
Barley-chaff,	20.2	5.4	20.0	$3 05
Barley-straw,	26.2	6.0	41.8	3 70
Bean-shells,	34.0	6.0	70.0	6 45
Beet leaves,	7.0	2.0	10.0	1 20
Buckwheat-hulls,	12.0	8.0	20.0	2 40
Cabbage leaves,	8.0	4.0	5.0	1 15
Cabbage-stalks,	3.6	4.8	10.2	95
Carrots (stalks and leaves),	10.2	4.2	7.4	1 50
Corn-cobs,	10.0	1.2	12.0	1 35
Corn-husks,	3.6	1.4	4.4	95
Corn-stalks,	5.6	2.8	8.2	1 00
Hop leaves and stems,	15.0	8.0	17.6	2 50
Mangel-wruzel leaves,	6.0	1.6	8.2	1 00
Millet chaff,	15.0	3.5	9.0	2 60
Oak leaves,	16.0	6.8	3.0	2 00
Oat-chaff,	15.0	2.8	9.0	1 95
Oat-straw,	12.4	4.0	24.8	2 40
Pea-shells,	27.2	11.0	27.6	4 25
Pea-straw (cut in bloom),	45.8	13.6	46.4	7 00
Pea-straw (ripe),	20.8	7.0	20.2	3 15
Potato stalks and leaves,	12.0	3.0	9.0	1 70
Rape-straw,	9.6	5.0	22.5	2 05
Rye-chaff,	12.0	11.0	10.0	2 05
Rye-straw,	9.5	5.6	18.0	1 90
Turnip stalks and leaves,	6.0	2.6	4.8	90
Wheat-chaff,	15.8	14.0	8.4	2 50
Wheat-straw,	11.8	2.4	10.2	1 70
5. Roots, Bulbs, Tubers, Etc.				
Beets (red),	4.8	1.8	8.8	90
Beets (sugar),	5.0	2.0	10.0	95
Beets (yellow fodder),	3.8	1.8	9.2	80
Carrots,	3.0	2.0	10.0	80
Mangolds,	4.0	2.0	8.0	80
Parsnips,	5.0	4.0	10.0	1 05
Potatoes,	6.4	3.0	10.0	1 15
Rutabagas,	4.0	2.5	10.0	90
Turnips,	4.0	2.0	8.0	80
6. Grains and Other Seeds.				
Barley,	35.0	15.0	12.0	4 60
Beans,	80.0	24.0	24.0	9 90
Buckwheat,	28.8	8.8	4.2	3 40
Clover,	60.0	25.0	25.0	8 00
Corn kernels,	36.4	14.0	8.0	4 50
Corn kernels and cobs, cob-meal,	30.0	12.0	8.8	3 85
Hempseed,	50.0	35.0	20.0	7 20
Linseed,	64.0	26.0	20.0	8 25
Millet, common,	40.0	15.0	8.0	4 90
Millet, Japanese,	35.0	14.0	8.0	4 40
Mustard,	85.0	30.0	12.0	10 20
Oats,	40.0	16.0	12.0	5 15
Peas,	80.0	16.0	20.0	9 45
Rye,	35.0	16.0	11.0	4 60
Soja-beans,	106.0	38.0	40.0	13 70
Sorghum,	30.0	16.0	8.5	4 00
Sunflower,	45.0	25.0	15.0	6 10
Wheat,	47.0	16.0	11.0	5 80
7. Mill Products.				
Barley flour,	32.0	19.0	11.5	4 40
Barley bran,	35.0	18.0	16.5	4 90
Barley meal,	31.0	13.0	7.0	3 90
Barley middlings,	40.0	35.0	14.0	5 95
Buckwheat bran,	50.0	25.0	25.0	7 00
Buckwheat middlings,	92.8	69.0	62.5	14 55
Corn-meal,	35.0	13.0	9.0	4 40
Corn-and-cob-meal,	28.0	12.0	10.0	3 70
Corn-middlings,	28.0	7.0	4.5	3 25
Oat bran,	27.0	4.4	14.0	3 45
Oat middlings,	37.0	45.0	30.5	6 70
Oats ground,	37.0	15.0	12.0	4 80
Pea meal,	60.0	16.0	20.0	7 75

Hay and Dry Coarse Fodders—Green Fodders, Etc.—Continued.

	Pounds of nitrogen in one ton.	Pounds of phosphoric acid in one ton.	Pounds of potash in one ton.	Approximate fertilizing valuation of 2,000 pounds.
Pea middlings,	75.0	13.0	15.0	$8 60
Rye-bran,	46.0	55.0	33.0	8 10
Rye-flour,	34.0	17.0	13.0	4 60
Rye-middlings,	40.0	25.0	18.0	5 70
Wheat-bran,	53.0	58.0	32.0	8 90
Wheat-flour,	44.0	11.4	10.6	5 28
Wheat-middlings,	52.5	19.0	12.5	6 50
Wheat-shorts,	48.4	27.5	13.0	6 45
8. Fruits.				
Apples,	2.6	0.2	4.0	45
Apricots,	3.8	1.2	6.0	65
Blackberries,	3.0	2.0	4.0	55
Cherries,	3.6	1.2	4.0	55
Grapes,	3.2	1.8	5.5	65
Pears,	2.0	0.6	1.6	30
Plums,	3.6	0.4	5.0	60
Prunes,	3.2	1.4	6.2	60
Raspberries,	3.0	10.0	7.0	1 00
Strawberries,	3.0	2.2	6.0	55
9. Vegetables.				
Asparagus stems,	6.0	1.6	6.0	90
Beets, red,	5.0	2.0	9.0	95
Cabbages,	7.6	2.2	9.0	1 20
Carrots,	3.2	2.0	10.0	80
Cauliflower,	2.6	3.2	7.2	70
Celery,	4.8	4.4	15.0	1 25
Cucumbers,	3.2	2.4	4.8	65
Horse-radish root,	8.0	2.0	20.0	1 70
Lettuce,	4.6	1.4	7.4	80
Onions,	4.0	2.5	3.5	65
Peas, garden (fresh),	23.0	6.0	8.5	2 90
Pumpkins, whole fruit,	2.2	3.2	2.0	45
Rhubarb, stems and leaves,	2.6	0.4	7.2	55
Spinach,	10.0	3.2	5.4	1 35
Sweet corn cobs,	4.2	1.0	4.4	65
Sweet corn husks,	3.6	1.4	4.4	60
Sweet corn kernels,	9.2	1.4	4.8	1 15
Sweet corn stalks,	5.6	2.8	8.2	1 00
Sweet potato,	4.8	2.0	10.0	95
Tomatoes, fruit,	3.2	1.0	5.4	60
Tomatoes, vines,	6.4	1.4	10.0	1 10
10. Dairy Products.				
Butter,	2.5	1.0	0.5	35
Buttermilk,	10.0	3.0	3.0	1 65
Cheese, whole-milk,	75.0	15.0	6.0	11 40
Cheese, half-skim,	105.0	15.0	6.0	15 60
Cheese, separator-skim,	150.0	15.0	6.0	21 90
Cream,	10.0	3.0	2.6	1 65
Milk,	10.0	6.0	3.5	1 80
Skim-milk,	10.0	7.0	4.0	1 90
Whey,	2.5	6.0	3.0	75
11. Farm Animals and Animal Products.				
Blood, calf,	60.0	1.5	1.5	8 50
Blood, ox,	65.0	1.0	1.5	9 20
Blood, sheep,	65.0	1.0	1.0	9 20
Blood, swine,	60.0	2.0	3.0	8 60
Eggs,	45.0	7.5	3.0	6 75
Flesh, calf,	70.0	12.0	8.0	10 60
Flesh, ox,	72.0	9.0	10.0	10 85
Flesh, swine,	70.0	9.0	8.0	10 50
Wool, unwashed,	110.0	1.5	115.0	20 00
12. By-products and Waste Materials.				
Apple-pomace,	4.6	0.4	2.6	60
Corn-cobs,	10.0	1.2	12.0	1 55
Cottonseed-hulls,	15.0	3.6	21.6	2 50
Cottonseed-meal,	133.0	54.0	36.0	19 60
Glucose refuse (starch feed),	52.4	6.0	3.0	5 60
Gluten-meal,	100.0	6.5	1.0	12 30
Gluten feed,	70.0	7.5	1.5	7 35

Hay and Dry Coarse Fodders—Green Fodders, Etc.—Concluded.

	Pounds of nitrogen in one ton.	Pounds of phosphoric acid in one ton.	Pounds of potash in one ton.	Approximate fertilizing valuation of 2,000 pounds.
Chicago gluten meal,	110.0	6.0	2.0	$11 35
Grano gluten feed,	100.0	13.0	4.0	10 70
Germ meal,	70.0	12.3	6.0	7 75
Hominy feed,	32.6	20.0	10.0	4 45
Hop refuse,	20.0	4.0	2.0	2 25
Linseed-meal, old process,	110.0	33.0	27.0	15 60
Linseed-meal, new process,	115.0	37.0	28.0	16 45
Malt sprouts,	71.0	29.0	33.0	9 60
Spent brewers grains, dry,	61.0	25.0	31.0	8 35
Spent brewers grains, wet,	18.0	6.0	1.0	2 10
13. Animal Manures.				
Chicken manure (fresh),	30.0	25.0	15.0	11 20
Cattle manure (fresh),	5.0	6.0	4.0	1 10
Cattle urine (fresh),	11.6	....	10.0	2 10
Duck manure (fresh),	20.0	28.0	12.4	4 40
Horse manure (fresh),	11.6	5.6	10.6	2 25
Horse urine (fresh),	31.0	....	30.0	5 85
Human excrement(fresh),	16.0	12.6	5.0	3 15
Human urine (fresh),	12.0	3.4	4.0	2 05
Mixed cattle manure,	9.0	5.0	8.0	1.60
Mixed horse manure,	10.0	6.0	14.0	2 30
Mixed pig manure,	15.0	8.0	6.0	2 35
Mixed sheep manure,	20.0	2.0	24.0	3 45
Mixed stable manure,	10.0	5.0	10.0	1 80

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